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F. T. G. — Francis Temple Grey, M.A.
Of Wadham College, Oxford, and of Lincoln's Inn, Barrister-at-Law. Assistant Honorary Secretary of the International Law Association and of the Grotius Society. Member of the representative body of the British Medical Association. Assistant Deputy Coroner, County of London. Late Surgeon, Royal Navy. — **Medical Jurisprudence** (*in part*).

F. W. Ha. — Frank W. Halliday, A.M.
Major, Judge-Advocate General's Department, United States Army. — **Military Law** (*in part*).

F. W. La. — Frederick William Lanchester, M.Inst.C.E., M.Inst.M.E., M.Inst.A.E., F.R.S.
Consulting Engineer and Technical Adviser to the Birmingham Small Arms Co., Ltd., and the Daimler Co., Ltd. Author of *Aerial Flight; Aircraft in Warfare,* etc. — **Motor Car** (*in part*).

G. Ab. — Grace Abbott, LL.D.
Formerly Chief of United States Children's Bureau, Washington. Professor, School of Social Service, University of Chicago. Author of *Immigrant and the Community,* and articles and reports on child welfare. — **Maternity and Infant Welfare** (*in part*).

G. C. E. — George C. Engerrand, B.S.
Associate Professor of Anthropology, University of Texas, Austin, Tex. Formerly Chief Geologist, Instituto Geologico Nacional, Mexico. Author of *Six Leçons de Prehistoire.* — **Mexico** (*in part*).

G. C. R. — Guy Colwin Robson, M.A.
Assistant Keeper in the Department of Zoology, British Museum. — **Mollusca.**

G. C. W. — George Charles Williamson, Litt.D.
Chevalier of the Légion d'Honneur. Author of *Portrait Miniatures; Life of Richard Cosway, R.A.; George Engleheart;* etc. Editor of *Bryan's Dictionary of Painters and Engravers.* — **Miniature Painting** (*in part*).

G. D. H. C. — George Douglas Howard Cole, M.A.
University Reader in Economics, Oxford. Author of *The World of Labour; Self Government in Industry; Guild Socialism Restated; Social Theory;* etc. — **Minimum Wage** (*in part*).

G. F. B. — George Frederick Barwick, B.A.
Keeper of Printed Books, British Museum, 1914–9. Assistant Keeper and Superintendent, Reading Room, British Museum, 1900–14. — **Midhat Pasha.**

G. F. Z. — George Frederick Zimmer, A.M.Inst.C.E.
Consulting Engineer and Joint Editor of *Engineering and Industrial Management.* Author of *Mechanical Handling;* etc. — **Mechanical Handling; Monorails and Telphers.**

G. G. — George Glasgow.
Author and Publicist. Author of *The Minoans; Ronald Burrows, a Memoir;* etc. — **Masaryk, Thomas Garrigue.**

G. G. A. — Major-General Sir George G. Aston, K.C.B.
Lecturer on Naval History, University College, London. Formerly Professor of Fortification at the Royal Naval College, Greenwich. Author of *Sea, Land and Air Strategy; Memories of a Marine; The Navy of Today; The Biography of Marshal Foch.* Editor of *The Study of War.* — **Morocco** (*in part*).

G. G. Si. — George Gaylord Simpson, Ph.D.
Assistant Curator of Vertebrate Palaeontology, The American Museum of Natural History, New York. Author of *A Catalogue of the Mesozoic Mammalia in the Geo-* — **Multituberculata.**

G. H. B.	REV. GEORGE HERBERT BOX, M.A., HON.D.D. Rector of Sutton, Beds. Hon. Canon of St. Albans. Davidson Professor of Old Testament Studies in the University of London.	**Messiah.**
G. L. B.	GUY LESLIE BUCKERIDGE, M.R.C.S., L.R.C.P. Surgeon-Commander in the Royal Navy.	**Medical Service, Navy** (*in part*).
G. Sa.	GEORGE EDWARD BATEMAN SAINTSBURY, LL.D., D.LITT., F.B.A. Professor of Rhetoric and English Literature at Edinburgh University, 1895–1915. Author of *Essays on French Novelists; Short History of French Literature; Short History of English Literature.* *See* the biographical article: SAINTSBURY, G. E. B.	**Mérimée, Prosper.**
G. Sc.	G. SCHOTT. Oceanographer German Naval Observatory, Hamburg. Hon. Professor of Oceanography, University of Hamburg.	**Mediterranean Sea** (*in part*).
G. S. D.	GEOFFREY SPENCE DAVISON. Technical Journalist. Late Assistant Editor of *Motor Cycling.*	**Motorcycles** (*in part*).
G. T. M.	GILBERT T. MORGAN, O.B.E., D.Sc., F.I.C., F.R.S. Director, Chemical Research Laboratory, Department of Scientific and Industrial Research, London. Formerly Mason Professor of Chemistry, University of Birmingham, Professor in the Faculty of Applied Chemistry, Royal College of Science for Ireland, and Professor of Applied Chemistry, Technical College, Finsbury. Author of *Organic Compounds of Arsenic and Antimony.* Editor of the Chemistry section of the 14th Edition of the *Encyclopædia Britannica.*	**Mercury; Methyl Alcohol.**
G. T. P.	GEORGE THURLAND PRIOR, D.Sc., F.G.S., F.R.S. Keeper of the Department of Mineralogy, Natural History Museum, South Kensington, London, 1909–27. President of Mineralogical Society since 1927.	**Meteorite.**
G. W. Cu.	G. W. CUSSONS. Of the firm of Messrs. G. Cussons Ltd., makers of scientific and technical apparatus for education, research and industry, Manchester.	**Mathematical Models.**
G. W. W.	GEORGE W. WATSON, M.I.MECH.E. Past President of the Institute of Automobile Engineers.	**Motor Vehicles, Commercial** (*in part*).
H. A.	HARRISON ATWOOD, A.B. Vice-President, The H. K. McCann Company, New York.	**Merchandise Marks** (*in part*).
H. Ah.	HAKON AHLBERG. Professor of Ornamental Architecture, Royal Technical College, Stockholm University.	**Modern Architecture** (*in part*).
H. C.	HUGH CHISHOLM, M.A. Editor of the 11th and 12th Editions of *The Encyclopædia Britannica.*	**Meredith, George.**
H. Ca.	HELEN CAM, M.A., F.R.HIST.S. Lecturer in History, Girton College, Cambridge. Probationer and University Lecturer in History, University of Cambridge. Author of *Studies in the Hundred Rolls.*	**Mayor** (*in part*).
H. Co.	HUGH L. COOPER. Hydraulic Engineer. Chief Engineer, Mississippi River Power Co. Hon. Professor of Civil Engineering, Republic of Brazil Government School of Engineering. Designed 612,000-h.p. water-power project at Muscle Shoals, Alabama.	**Muscle Shoals.**
H. D. A. M.	REV. HENRY DEWSBURY ALVES MAJOR, D.D., F.S.A. Principal of Ripon Hall, Oxford. Examining Chaplain to the Bishop of Birmingham. Editor of the *Modern Churchman.* Author of *English Modernism.*	**Modernism.**
H. D. K. D.	H. D. K. DREW, D.Sc., PHD., F.I.C. Lecturer in Chemistry and Superintendent of the Microanalytical Laboratory, University of Birmingham.	**Microanalysis, Chemical.**
H. Fo.	HENRY FORD. Organiser and President of the Ford Motor Co. Author (with Samuel Crowther) of *My Life and Work.*	**Mass Production.**
H. G. B.	HARRY G. BEASLEY. Founder of the Cranmore Ethnographical Museum. Author of *Pacific Island Records.*	**Micronesia.**
H. Goe.	HERMANN GOETZ, PH.D. Volunteer Assistant in Charge of the Mohammedan Collections, Museum of Ethnology, Berlin.	**Mohammedan Architecture; Mohammedan Art.**
H. H. Go.	HENRY HERBERT GODDARD, A.M., PH.D. Professor of Abnormal and Clinical Psychology, Ohio State University, Columbus, Ohio. Formerly Director of Research at the Training School for Mental Defectives, Vineland, N. J. Author of *Feeblemindedness, Causes and Consequences.*	**Mental Deficiency** (*in part*).
H. H. L. B.	HUGH HALE LEIGH BELLOT, M.A., D.C.L. Late Associé de l'Institut de Droit International and Honorary Secretary, International Law Association, and Grotius Society. Sometime Acting Professor of Constitutional Law, University of London. Author of *Commerce in War; Permanent Court of International Justice.*	**Master of the Rolls; Mediation** (*in part*); **Money-Lending** (*in part*); **Most Favoured Nation Clause.**
Hi. Br.	HENRI BRENIER. Director-General of the Chamber of Commerce, Marseilles. General Secretary to the National Colonial Exhibition of Marseilles, 1922, and to the Colonial Organisation Congress, 1922.	**Morocco** (*in part*).
H. Ja.	SIR HERBERT JACKSON, K.B.E., F.R.S. Director of Research, British Scientific Instruments Research Association. Emeritus Professor of Chemistry, University of London. Formerly Daniell Professor of Chemistry, King's College, London.	**Microscope** (*in part*); **Microscopy** (*in part*).
H. J. Ch.	HENRY JAMES CHANEY, I.S.O. Late Superintendent of the Standards Department of the Board of Trade, and Secretary of the Royal Commission on Standards.	**Measures and Weights** (*in part*).

H. K. C.	Henry King Carroll, LL.D. Author of *Religious Forces in the United States; Missionary Growth of the Methodist Episcopal Church.*	Mennonites (*in part*); Moravian Brethren (*in part*).
H. Mo.	H. Moore, D.Sc. Assistant Director of Research of the British Scientific Instrument Research Association.	Microscope (*in part*); Microscopy (*in part*).
H. M. St.	Henry Morse Stephens, M.A., Litt.D. Late Professor of History in the University of California. Author of *History of The French Revolution;* etc.	Mazarin, Jules (*in part*); Mirabeau, Honoré Gabriel Riqueti.
H. M. T.	Horace M. Towner, LL.B. Governor of Porto Rico.	Mayagüez.
H. N.	H. Nisbet, F.T.I. Textile Technologist and Consultant. Author of *Grammar of Textile Design.*	Moiré.
H. N. D.	Henry Newton Dickson, M.A., D.Sc., F.R.G.S., F.R.S.E. Late Professor of Geography, University College, Reading. Author of *Meteorology; Papers on Oceanography;* etc.	Mexico, Gulf of.
H. Pal.	Howard Palmer, B.A., LL.B., F.R.G.S. Explorer. Author of *Mountaineering and Exploration in the Selkirks; A Climber's Guide to the Rocky Mountains of Canada;* etc.	Mountaineering (*in part*).
H. R.	Sir Humphry Davy Rolleston, K.C.B., M.D., Hon.D.Sc., LL.D., D.C.L. Physician-in-Ordinary to the King. Regius Professor of Physic, University of Cambridge. Consulting Physician to the Royal Navy. Examiner in the Universities of Oxford, Cambridge, London, etc. Formerly President of the Royal College of Physicians. Author of *Clinical Lectures;* etc., and Joint-Editor (with Sir Clifford Allbutt) of 2nd Edition of *A System of Medicine.*	Medicine, General.
H. S. H.	H. S. Harrison, D.Sc. Curator, The Horniman Museum, London.	Material Culture.
H. St.	Henry Sturt, M.A. Author of *Idola Theatri; The Idea of a Free Church; Personal Idealism.*	Metempsychosis (*in part*).
H. W. C. D.	Henry William Carless Davis, M.A. Late Director, *Dictionary of National Biography,* Regius Professor of Modern History and Fellow and Tutor of Balliol College, Oxford.	Montfort, Simon de (*in part*).
H. W. H.	Hope W. Hogg, M.A. Late Professor of Semitic Languages and Literatures in the University of Manchester, England.	Mesopotamia (*in part*).
H. Wit.	Hartley Withers. Editor of the *Economist* (London), 1916–21. Director of Financial Enquiries in the Treasury, 1915–6. Sometime City Editor of *The Times* and *Morning Post* (London). Author of *Money; International Finance;* etc.	Money Market (*in part*).
H. W. L. E.	H. W. L. Evans, O.B.E. Superintendent of the Royal Mint.	Mint (*in part*).
H. Wo.	Humbert Wolfe, C.B., C.B.E. Poet and Writer. Principal Assistant Secretary, Ministry of Labour. Substitute British Government Member, Governing Body, International Labour Office. Author of *London Sonnets; Circular Saws; The Unknown Goddess; The Uncelestial City, Sonnets for Helen; Salvation Somehow; The Silver Cat; Dialogues and Monologues, Now a Stranger; The Wall of Weeping;* etc.	Moore, George.
H. W. R.	Rev. Henry Wheeler Robinson, M.A., D.D. Principal of Regent's Park College, London. Formerly Professor of Church History and the Philosophy of Religion in Rawdon College, Leeds. Author of *Hebrew Psychology in Relation to Pauline Anthropology* (in Mansfield College Essays); etc.	Micah.
I. A.	Israel Abrahams, M.A. Formerly Reader in Talmudic and Rabbinic Literature in the University of Cambridge. Author of *A Short History of Jewish Literature; Judaism;* etc.	Menasseh Ben Israel.
I. A. R.	Irma A. Richter. Artist and Writer.	Masaccio; Masolino da Panicale; Moretto, Il.
Ja. H.	James Henderson, M.A., B.Sc. Assistant Lecturer in Mathematics at King's College in the University of London.	Mathematical Tables.
J. A. Si.	Judith Ann Silburn. Diplomée of Domestic Science, M.I.H. Formerly Trade Investigator, Ministry of Labour. Journalist and Domestic Science Consultant.	Meat Cookery.
J. A. Th.	Sir John Arthur Thomson, M.A., LL.D. Regius Professor of Natural History in the University of Aberdeen. Terry Lecturer, Yale University, 1934. Author of *The Study of Animal Life; Outlines of Zoology; Heredity; Darwinism and Human Life; What Is Man?; Concerning Evolution.* Joint-Author (with Professor Patrick Geddes) of *Evolution; Sex; Biology.*	Migration of Animals.
J. A. V.	Rev. J. A. Vanes. Formerly Professor of New Testament Exegesis at Wesleyan College, Richmond, Virginia.	Methodism (*in part*).
J. Bt.	James Bartlett. Late Lecturer on Construction, Architecture, Sanitation, Quantities, etc., at King's College, London. Author of *Quantities.*	Masonry.
J. C. Pr.	James C. Pryor. Captain, Medical Corps, United States Navy. Senior Medical Officer, United States Naval Academy. Author of *Naval Hygiene.*	Medical Service, Navy (*in part*).

J. D. du S. — J. Dionis du Sejour.
Managing Director, Compagnie des Messageries Maritimes. } Messageries Maritimes, Compagnie des.

J. D. M. S. — J. D. Main Smith, Ph.D., B.Sc., A.I.C.
Late Research Assistant to the Professor of Chemistry, University of Birmingham. Late Assistant Examiner in Chemistry, University of London. Author of *Chemistry and Atomic Structure;* etc. } Molecule, Chemical.

J. E. — Rev. John Elsworth.
Minister of the Wesleyan Methodist Church. Member of Committees for arranging the details of Methodist Reunion. } Methodism (*in part*).

J. E. A. D. — Commandant J. E. A. Doumenc.
Officer of the Legion of Honour, Director of the French Army Mechanical Transport Service during the World War. Author of *Les Transports Automobiles sur le front français.* } Motor Transport, Military (*in part*).

J. E. S. — J. E. Sears, C.B.E., M.A., M.I.Mech.E., A.M.Inst.C.E., F.Inst.P.
Deputy Warden of the Standards, Board of Trade, London, and Superintendent of the Metrology Department, National Physical Laboratory, Teddington, Middlesex. } Metrology.

J. F. C. F. — Colonel John Frederick Charles Fuller, C.B.E., D.S.O.
Military Assistant to the Chief of the Imperial General Staff. Chief General Staff Officer, Tank Corps, 1917–8. Formerly Chief Instructor, Camberley. } Mountain Warfare (*in part*); Munda, Battle of; Mursa, Battle of.

J. G. R. — John George Robertson, M.A., Ph.D.
Professor of German Language and Literature in the University of London. Author of *History of German Literature; Schiller After a Century;* etc. } Meistersinger.

J. H. — John Hilton.
Director of Statistics, Ministry of Labour, London. } Monopoly.

J. Har. — J. Harada.
Of the Imperial Household Museums, Japan. Formerly Professor in the Nagoya College of Technology and in the 8th Higher School. Imperial Japanese Government Commissioner, Panama-Pacific International Exposition, San Francisco, 1915. } Museums and Art Galleries (*in part*).

J. H. B. — Joseph H. Bonneville, A.M.
Department of Banking and Finance, New York University School of Commerce, Accounts and Finance. Author of *Elements of Business Finance.* } Money-Lending (*in part*).

J. H. D. — J. H. Driberg.
Author of *The Lango, a Nilotic Tribe of Uganda.* } Masai.

J. H. H. — J. H. Hutton, D.Sc., C.I.E.
Director of Ethnology, Assam. Deputy Commissioner, Naga Hills. Author of *The Angami Nagas; The Sema Nagas;* etc. } Meithei; Metempsychosis (*in part*); Moro.

J. H. Mi. — John Henry Middleton, M.A., Litt.D., F.S.A., D.C.L.
Author of *The Engraved Gems of Classical Times; Illuminated Manuscripts in Classical and Mediaeval Times.* } Monreale (*in part*).

J. Jn. — J. Jackson, M.A., D.Sc.
Chief Assistant, Greenwich Royal Observatory. } Moon.

J. J. P. — General John Joseph Pershing, G.C.B.
Chief of Staff, United States Army, 1921–4. Commander-in-Chief, American Expeditionary Forces in Europe, 1917–9. } Meuse-Argonne Operation.

J. J. Si. — J. J. Simpson, M.A., D.Sc.
Free Public Museums, Liverpool. } Museums of Science (*in part*).

J. L. Ha. — John L. Haughton, D.Sc., F.Inst.P., F.R.A.S.
Senior Assistant in the Metallurgy Department, National Physical Laboratory, Teddington. } Metals.

J. L. La. — Jesse L. Lasky.
President, Jesse L. Lasky Feature Play Co. Vice-President, Famous Players Lasky Corporation. } Motion Pictures (*in part*).

J. L. W. — Jessie L. Weston, Litt.D.
Author of *Arthurian Romances.* } Merlin.

J. M. M. — John Malcolm Mitchell, O.B.E., M.C., F.S.A.
Secretary, Carnegie United Kingdom Trust. Vice-President, Library Association. Assistant Editor for Classics, Archaeology, Ancient History, 11th Edition, *Encyclopædia Britannica.* } Mnemonics.

J. Pa. — John Palmer.
Formerly Dramatic Critic and Assistant Editor of the *Saturday Review.* } Molière.

J. P. M. — J. P. Mills, M.A., I.C.S.
Assistant Commissioner, Makokehung, Assam. } Mikir.

J. P. V.-S. — Lieut.-Colonel J. P. Villiers-Stuart, C.B., D.S.O., O.B.E.
Served N.W. Frontier, India, 1901–2; East Africa, 1903–4; European War, 1914–8. } Mountain Warfare (*in part*).

J. S. B. — John Sutherland Black, M.A., LL.D.
Assistant Editor of 9th Edition, *Encyclopædia Britannica.* Joint-Editor of the *Encyclopaedia Biblica.* } Mazzini, Giuseppe (*in part*).

J. S. F. — Sir John Smith Flett, K.B.E., D.Sc., LL.D., F.R.S.
Director, Geological Survey of Great Britain and Museum of Practical Geology. Formerly Lecturer on Petrology in Edinburgh University. } Micropegmatite.

J. S. Fa. — John Shields Fairbairn, M.B., B.Ch., F.R.C.S., F.R.C.P.
Obstetric Physician and Lecturer on Midwifery and Diseases of Women, St. Thomas' Hospital. Physician, General Lying-in Hospital, London. Author of *A Textbook for Midwives; Gynaecology with Obstetrics;* etc. } Menopause.

R. H. Ch.	REV. ROBERT HENRY CHARLES, M.A., D.D., LITT.D., F.B.A. Archdeacon of Westminster. Late Grinfield Lecturer and Lecturer in Biblical Studies, Oxford. Professor of Biblical Greek at Trinity College, Dublin, 1898–1906.	**Moses, Assumption of.**
R. H. R.	SIR R. HENRY REW, K.C.B. Board of Agriculture and Fisheries, 1898; Assistant Secretary, 1906–18. Secretary to the Ministry of Food, 1916–7. Chairman, Inter-Departmental Committee on Unemployment Insurance in Agriculture, 1925–6.	**Meat Trade** (*in part*).
R. K. D.	SIR ROBERT KENNAWAY DOUGLAS. Author of *The Language and Literature of China; The Life of Jenghiz Khan;* etc.	**Mongols** (*in part*).
R. N. B.	ROBERT NISBET BAIN. Assistant Librarian, British Museum, 1883–1909. Author of *Scandinavia: The Political History of Denmark, Norway and Sweden, 1513–1900; Slavonic Europe: The Political History of Poland and Russia from 1469 to 1766;* etc.	**Menshikov, A. D.** (*in part*).
R. Sc.	ROBERT SCOTT, M.B., CH.B. Barrister-at-Law. Formerly Major in the R.A.M.C.	**Medical Legislation** (*in part*).
R. S. Cl.	R. S. CLAY, D.SC., F.INST.P. Principal, Northern Polytechnic, Holloway, London. President of Optical Society. Author of *Practical Exercises in Light; Treatise on Practical Light.*	**Mirror.**
R. S. L.	R. S. LEWIS, A.B., E.M. Department of Mining, University of Utah, Salt Lake City, Utah. Author of section on Boring, *Peele's Mining Engineers' Handbook.*	**Mining, Metalliferous.**
R. Sm.	REED SMOOT. American Senator from Utah. Member of the World War Foreign Debt Commission. Regent of the Smithsonian Institution.	**Mormonism; Mormons or Latter-Day Saints.**
R. V. S.	RICHARD VYNNE SOUTHWELL, M.A., F.R.S. University Lecturer in Mathematics and Fellow of Trinity College, Cambridge. In charge of Non-Rigid Airships Design at R.N. Air Station, Kingsnorth, 1915–8, and of Aerodynamic and Structural Experiments at the Royal Aircraft Establishment, Farnborough, 1918–9.	**Materials, Strength of; Mechanics.**
R. W. M.	ROY WALDO MINER. Curator of the Marine Life section of the division of Zoology and Zoogeography, American Museum of Natural History.	**Museums of Science** (*in part*).
R. W. P.	RAYMOND WILLIAM POSTGATE. Editorial Staff, London, of the 14th Edition of the *Encyclopædia Britannica.* Author of *Revolution from 1789-1906; The Builders' History;* ed. *Pervigilium Veneris.*	**Municipal Trading** (*in part*).
R. W. Pe.	SIR ROBERT WILLIAM PERKS, BART. Chairman of the Metropolitan District Railway, 1902–6. Treasurer, Wesleyan Methodist Twentieth Century Million Fund.	**Methodism** (*in part*).
R. W. S.-W.	ROBERT WILLIAM SETON-WATSON, LITT.D. Masaryk Professor of Central European History at King's College, University of London. Founder of and Joint-Editor of *The New Europe,* 1916-20. Joint-Editor of *The Slavonic Review.* Author of *The Rise of Nationality in the Balkans;* etc.	**Montenegro.**
S. A. C.	STANLEY ARTHUR COOK, M.A., LITT.D. University Lecturer in Hebrew and Aramaic. Fellow and Lecturer in Hebrew and Syriac, Gonville and Caius College, Cambridge. Co-Editor of the *Cambridge Ancient History.* Editor for Palestine Exploration Fund.	**Moab; Moloch** (*in part*); **Moses** (*in part*).
S. Au.	S. AUERBACH. Secretary, Metallgesellschaft, Frankfurt.	**Metallgesellschaft A. G.**
S. C.	SIR SIDNEY COLVIN, M.A. English Literary and Art Critic. Late Slade Professor of Fine Art, Cambridge University. Keeper of the Department of Prints and Drawings, British Museum, 1884–1921. *See* the biographical article: COLVIN, SIR SIDNEY.	**Michelangelo** (*in part*).
S. C. H. D.	S. C. H. DAVIS. Of Autocar, London.	**Motor Racing** (*in part*).
S. Cu.	STEWART CULIN. Brooklyn Museum of Art and Sciences, Brooklyn, N. Y. Author of *Korean Games; Games of the American Indians.*	**Masks** (*in part*).
S. G. B.-B.	REV. GRAHAM BRADE-BIRKS, D.SC., F.Z.S. Lecturer in Zoology and Geology, South-Eastern Agricultural College, Wye, Kent.	**Millipede.**
S. H. H.	S. H. HAMER. Secretary of the National Trust for Places of Historic Interest or Natural Beauty, 1911. Author of *The Story of the Ring; Whys and Other Whys; The Jungle School;* etc.	**Monuments, Preservation of** (*in part*).
S. J. Bu.	SOLON JUSTUS BUCK, PH.D. Superintendent of the Minnesota Historical Society. Professor of History in the University of Minnesota. Author of *The Granger Movement; Illinois in 1818;* etc.	**Minnesota.**
S. L.	STEPHEN HERBERT LANGDON, M.A., B.D., PH.D. Professor of Assyriology, Oxford, since 1919. Curator in the University Museum, Babylonian section, Philadelphia, 1916–8. Director of the Weld-Blundell and Field Museum Expedition to Mesopotamia since 1922.	**Mesopotamia** (*in part*).
S. L. A.	S. L. AVERY. President and Chairman of the Board, Montgomery Ward & Company, Chicago.	**Montgomery Ward & Company, Inc.**
S. Le.	STUART LEWIS, A.M., PH.D., D.C.L., M.F.S. Professor of Law, New Jersey Law School. Author of *Party Principles and Practical Politics; An Outline of American Federal Government.*	**Mason and Dixon Line.**
S. S. R.	REAR-ADMIRAL SAMUEL S. ROBISON, U.S.N. Superintendent of United States Naval Academy.	**Midshipman** (*in part*).

S. W. S.	Samuel Wesley Stratton, D.Sc., LL.D., Ph.D. Formerly President of Massachusetts Institute of Technology, Boston.	**Massachusetts Institute of Technology, The.**
T. A.	Thomas Ashby, D.Litt., F.B.A., F.S.A., Hon.A.R.I.B.A. Formerly Director of the British School at Rome. Author of *Turner's Visions of Rome; The Roman Campagna in Classical Times;* Revised and completed for press a *Topographical Dictionary of Ancient Rome* (by the late Prof. J. B. Plattner).	**Megara Hyblaea; Messina; Metaurus; Monreale** (*in part*), **Monteleone Di Calabria.**
T. E. L.	Thomas East Lones, M.A., LL.D. Formerly Senior Examiner in H.M. Patent Office. Author of *Aristotle's Researches in Natural Science; Zinc and Its Alloys.*	**Meters, Electric.**
T. E. R. P.	Rev. Theodore Evelyn Reece Phillips, M.A., F.R.A.S., F.R.Met.S. Secretary, Royal Astronomical Society, 1919–26; President, 1927 and 1928. Joint-Editor of the *Splendour of the Heavens.*	**Mercury.**
T. F. H	Talbot F. Hamlin, B.A., B.Arch. Instructor in the History of Architecture, Columbia University, New York. Chairman, City Plan Committee of the Merchants' Association, New York.	**Minaret; Mosaic; Mosque; Moulding.**
T. G. B.	Thomas Gregor Brodie, M.D., F.R.S. Late Professor of Physiology at St. Thomas's Hospital Medical College, University of London.	**Muscle, Structure of.**
Th. N.	Theodor Nöldeke, Ph.D. German Semitic Scholar. Late Professor of Oriental Languages at Strasbourg. Author of *Geschichte des Korans* and numerous essays.	**Mo'allaqāt** (*in part*).
T. H. R.	Theodore H. Robinson, M.A., D.D. Professor of Semitic Languages, University College of South Wales and Monmouthshire.	**Moses** (*in part*).
T. J. W.	T. J. Walsh. American Lawyer and Senator.	**Montana.**
T. K. R.	Sir Thomas Kirke Rose, D.Sc., A.R.S.M. Chemist and Assayer at the Mint, 1902–26. President, Institution of Mining and Metallurgy, 1915–6. Author of *The Metallurgy of Gold; The Precious Metals.*	**Mint** (*in part*).
T. Ra.	Terry Ramsaye. Editor-in-Chief of Eastern Production for Pathé Exchange, Inc., New York. Author of *A History of the Motion Picture.*	**Motion Pictures** (*in part*).
T. R. Pi.	T. R. Pirtle. Department of Information, United States Department of Agriculture, Washington. Author of *History of the Dairy Industry; Handbook of Dairy Statistics.*	**Milk** (*in part*).
T. W.	Thomas Woodhouse. Head of Weaving and Textile Designing Department, Technical College, Dundee.	**Matting.**
T. W. A.	Sir Thomas Walker Arnold, C.I.E., M.A., Litt.D., F.B.A. Professor of Arabic, University of London. Formerly Professor of Philosophy, Government College, Lahore.	**Miniature Painting** (*in part*).
V. H. B.	Vernon Herbert Blackman, Sc.D., F.R.S. Professor of Plant Physiology and Pathology, Imperial College of Science and Technology, London. Editor of the Botany section of the 14th Edition of the *Encyclopædia Britannica.*	**Millet.**
W. A. Ba.	Walter A. Bardgett. Editor of cycling papers since 1915. Former Racing Cyclist, Manager of Bicycle tracks and referee at cycle race meets.	**Motorcycles** (*in part*).
W. A. G.	William A. Ganoe, A.M., M.A. Major, United States Army. Author of *The History of the United States Army.*	**Monterrey.**
W. A. Ha.	William A. Hamor. Assistant Director of Mellon Institute of Industrial Research. Author of *The Examination of Petroleum; American Fuels;* etc.	**Motor Car Engines: Their Operation and Care.**
W. A. P.	W. Alison Phillips, M.A. Lecky Professor of Modern History, Dublin University.	**Mephistopheles.**
W. B. P.	William Belmont Parker, A.B. Editor of *South Americans of Today.*	**Maximilian; Medina, José Toribio; Mendoza, Antonio De; Mitre, Bartolomé.**
W. B. Sh.	Wilfred B. Shaw. General Secretary, Alumni Association, University of Michigan. Author of *History of the University of Michigan.*	**Michigan, University of.**
W. D. M.	William Diller Matthew, A.M., Ph.D., F.R.S. Professor of Palaeontology. Director of Museum of Palaeontology, University of California. Author of various scientific treatises on fossil vertebrates.	**Megatherium.**
W. E. I.	Major-General Sir William Edmund Ironside, K.C.B., C.M.G., D.S.O. G. O. C. Meerut District, India, since 1928. Commander-in-Chief, British Troops in Russia, 1918–9. Commandant, Staff College, Cambridge, 1922–6. Author of *Tannenberg: The First Thirty Days in East Prussia.*	**Masurian Lakes, Battles of the.**
W. F. S.	William Fleetwood Sheppard, Sc.D., M.A., LL.M. Senior Examiner in the Board of Education. Formerly Fellow of Trinity College, Cambridge.	**Mensuration.**
W. G. Co.	William George Constable, M.A. Assistant Keeper of the National Gallery, London. Lecturer at the Wallace Collection. Fellow of St. John's College, Cambridge.	**Museums and Art Galleries** (*in part*).

W. G. Ma.	SIR WILLIAM GRANT MACPHERSON, K.C.M.G., M.B., D.P.H. Late Major-General, Army Medical Service. Editor-in-Chief, *Medical History of the War.* Served at the War Office as Deputy Director-General of the Army Medical Service, and as a member of the Advisory Board for Medical Services.	Medical Service, Army.
W. Gt.	W. GARNETT, B.SC. Of the Overseas Settlement Committee, London.	Migration (*in part*).
W. Ha.	WESLEY HARDENBERGH, B.LITT. Vice-President, Institute of American Meat Packers, Chicago.	Meat Trade (*in part*).
W. H. Di.	WILLIAM HEPWORTH DIXON. Chief of the Research Department, Messrs. Bryant and May, Ltd., London.	Match (*in part*).
W. H. Ma.	WILLIAM HERRICK MACAULAY, M.A. Fellow and Tutor of King's College, Cambridge.	Motion, Laws of.
W. J. B.-L.	W. J. BASSETT-LOWKE. Messrs. Bassett-Lowke, Ltd., Locomotive Engineers, Northampton, England.	Models and Model-Making.
W. K. G.	WILLIAM KING GREGORY, A.M., PH.D. Curator, Departments of Comparative Anatomy and Ichthyology, American Museum of Natural History. Professor, Vertebrate Palaeontology, Columbia University.	Monotremata.
W. K. L. C.	REV. WILLIAM KEMP LOWTHER CLARKE, D.D. Editorial Secretary of the Society for Promoting Christian Knowledge. Author of *St. Basil the Great;* etc.	Matthias (Disciple)
W. M. C.	SIR W. MARTIN CONWAY. English Art Critic and Mountaineer. Director-General of the Imperial War Museum since 1917. Author of *The Alps from End to End.*	Mountaineering (*in part*).
W. Me.	WILFRED MEYNELL. Editor of *The Collected Works of Francis Thompson.*	Meynell, Alice.
W. M. F. P.	SIR WILLIAM M. FLINDERS PETRIE, D.C.L., LITT.D., PH D , LL D , F R S. Edwards Professor of Egyptology, University College, London *See* the biographical article: PETRIE, SIR WILLIAM MATTHEW FLINDERS.	Measures and Weights, Ancient.
W. N. Ha.	WILLIAM N. HASKELL, D.S.M. Major-General, New York National Guard. Head of American Relief Missions to Rumania and Russia. Red Cross Commissioner in Greece, 1922-3.	Militia (*in part*)
W. Pa.	REV. W. PATON. Joint-Editor of *The International Review of Missions.*	Missions.
W. R. Be.	WILLIAM R. BENET, PH.B., M.A. Associate Editor of *Saturday Review of Literature,* New York.	Masters, Edgar Lee.
W. R. D.	WARREN R. DAWSON, F.R.S.E., F.S.A. Author of numerous articles on Egyptology and the History of Medicine.	Mummy.
W. R. Ho.	W. R. HODGKINSON, C.B.E., PH.D., F.R.S.E. Formerly Professor of Chemistry and Metallurgy, Artillery College, Woolwich Part Author of Valentine-Hodgkinson's *Practical Chemistry;* etc.	Mercury, Fulminate of.
W. Rn.	WALTER ROSENHAIN, D.SC., F.R.S. Superintendent, Department of Metallurgy in the National Physical Laboratory, Teddington, Middlesex. Author, *Introduction to the Study of Physical Metallurgy*	Metallography; Metallurgy.
W. R. S.	W. ROBERTSON SMITH, LL.D. Editor of the 9th Edition of the *Encyclopædia Britannica.*	Moloch (*in part*).
W. R. Sm.	WILLIAM ROY SMITH, M.A., PH.D. Associate Professor of History, Bryn Mawr College, Pennsylvania.	Missouri Compromise.
W. S. H.	WILLIAM S. HARLEY, B.S. Harley Davidson Motor Company, Milwaukee, Wisconsin.	Motorcycles (*in part*).
W. S. L.-B.	WALTER SYDNEY LAZARUS-BARLOW, B.A., M.D., F.R.C.P. Member of the Cancer Committee, Ministry of Health. Formerly Professor of Experimental Pathology, Middlesex Hospital Medical School, London University Editor, Medicine section, 14th Edition, *Encyclopædia Britannica.*	Medical Research; Medicine; Mirror-Writing; Mouth and Salivary Glands.
W. S. McL.	W. S. MCLEAN. Director of Advertising, Fisher Body Division, General Motors Corporation, Detroit	Motor Car (*in part*)
W. T. B.	WLADYSLAW THEODORE BENDA. Illustrator and Painter. Illustrates for leading American periodicals, *Century Magazine, Scribners;* etc. Creator of Benda Masks used on stage in Europe and America.	Masks (*in part*)
W. Tho.	WALLACE THOMPSON, B.SC., LITT.D. Editor-in-Chief of *Ingenieria International* (New York). Fellow of the Royal Geographical Society. Author of *The People of Mexico; Trading with Mexico;* etc.	Mosquito Coast.
W. T. W.	WILLIAM TEMPLETON WAUGH, M.A., B.D. Kingsford Professor of History and Chairman of the Department of History, McGill University, Montreal. Author of *The Monarchy and the People;* etc.	Montcalm, Louis-Joseph de Montcalm-Gozon.
W. Wa.	W. WARDLAW, D.SC., F.I.C. Lecturer in Chemistry, University of Birmingham.	Molybdenum (*in part*).
W. W. P.	W. WYATT PAINE, J.P., F.S.A. Author and Editor of numerous legal textbooks.	Master and Servant.
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THE ENCYCLOPÆDIA BRITANNICA

VOLUME 15

MARYBOROUGH TO MUSHET STEEL

MARYBOROUGH, a coastal town in the south-east of Queensland, Australia, situated 167 miles by rail north of Brisbane on the banks of the Mary river, *c.* 20 miles from its mouth. The lowlands here extend as far north as Bundaberg (*q.v.*), on the south to Gympie (*q.v.*), and inland (west) beyond Gayndah. Its extensive hinterland includes a variety of natural possibilities, mineral, forestal, pastoral and agricultural. (Av. ann. temps. 86°–49° F; av. ann. rainfall: 46 in.) In the Wide Bay district is the Burrum (Cretaceous; bituminous) coal-field. The ten coal-mines of the Maryborough district produced *c.* 100,000–120,000 tons (1925–26). The Gympie and Kilkivan mining fields also find their outlet at Maryborough. Inland, valuable timbers (*e.g.*, "Queensland kauri") are cut (Kingaroy district) and cattle and sheep rearing is carried on (*e.g.*, Gayndah area). Around the town, sugar (Isis district) and fruit growing, dairying and mixed farming are progressing, while Maryborough itself is noted for its foundry and railway engineering works, and other industries of the area are sugar milling and butter-making A good deep-water port exists at Urangan (29 miles N E) and, besides local lines (Gayndah, Nanango, etc.), Maryborough is connected by the North Coast Railway with Brisbane and the coastal towns further north. The population (1933) is 11,414.

MARYBOROUGH, county town of co. Leix, Ireland Pop. (1926) 3,382. It lies on the river Triogue and is 51 m. W.S.W. of Dublin by the Great Southern railway. Its charter was granted in 1570, and a bastion of the ancient castle remains. There are flour-mills and a considerable general trade. On Dunamase or Dunmall rock, about 3 m. from the town, are ruins of a castle belonging to the kings of Leinster, but probably built by William Bruce (*c.* 1200) and dismantled in 1650 by Cromwell's troops.

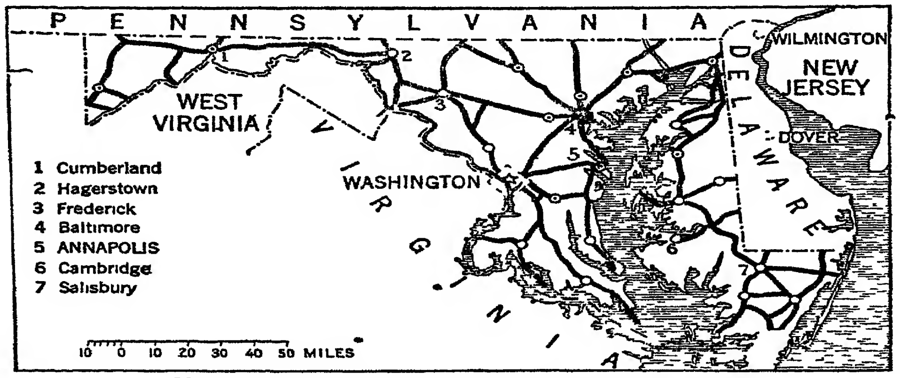
MARYLAND (mĕr'ĭ-land), the "Old Line State," is one of the original thirteen States of the United States of America. It is situated on the Atlantic coast and extends along the Chesapeake bay between lat. 37° 53′ and 39° 43′ 26·3″ N., the northern boundary being the Mason and Dixon line, and between long. 75° 4′ and 79° 29′ 15″ W. It is bounded north by Pennsylvania and Delaware; east by Delaware and the Atlantic ocean; south and west by the Potomac river and its north branch, which separates the State, except on the extreme west border, from Virginia and West Virginia; west by West Virginia. It is one of the small States of the Union—only seven are smaller—its total area being 12,327 sq.m., of which 2,386 sq.m. are water surface. The name Maryland was given to the original county palatine in honour of Queen Henrietta Maria, wife of Charles I. of England. The popular name "Old Line State" has been applied to Maryland because of the distinguished service of the Maryland Line during the Revolutionary War.

Physical Features.—Maryland is crossed from north to south by each of the leading topographical regions of the east section of the United States—the Coastal plain, the Piedmont plateau, and the Appalachian region; hence its great diversity of surface. The portion within the Coastal plain embraces nearly the whole of the south-east half of the State and is commonly known as tidewater Maryland. It is marked off from the Piedmont plateau by a "fall line" extending from Washington (D.C.) north-east through Baltimore to a point a little south of the north-east corner of the State, and is divided by the Chesapeake bay into two parts known as the eastern shore and the western shore. The eastern shore is a low, level plain, the least elevated section of the State. Along its entire Atlantic border extends the narrow sandy Sinepuxent beach which encloses a shallow lagoon or bay also called Sinepuxent at the north and Chincoteague at the south. On the entire peninsula between the Delaware and the Chesapeake the land is low, rising northward to a height of about 100 ft. near the fall line. A water-parting extending from north-east to south-west and close to the Atlantic border separates the eastern shore into two drainage systems, though that next to the Atlantic is insignificant. That on the Chesapeake side is drained chiefly by the Chester, Choptank, Nanticoke and Pocomoke rivers together with their numerous branches, the general direction of all of which is south-west. The branches, as well as the upper parts of the main streams, flow through broad and shallow valleys.

The western shore is somewhat more undulating than the eastern and also more elevated. Its general slope is from north-west to south-east, and along the west border are points 300 ft. or more in height. The principal rivers crossing this section are the Patuxent and the Potomac, the right or southern bank of the latter forming the State's southern boundary. These rivers, lined in most instances with terraces 30 to 40 ft. high on one or both sides, flow south-east into the Chesapeake bay through valleys bounded by low hills. The fall line, which forms the boundary between the coastal plain and the Piedmont plateau, is a zone in which a

descent of about 100 ft. or more is made in many places within a few miles, and in consequence is marked by waterfalls and rapids.

The part of Maryland within the Piedmont plateau extends west from the fall line to the base of Catoctin mountain, or the west border of Frederick county, and has an area of about 2,500 square miles. In general it has a broad rolling surface. It is divided into two sections by an elevated strip known as Parr's ridge, which extends from north-east to south-west a short distance west of the



MAP SHOWING THE MAIN ROADS IN MARYLAND

middle. The east section rises from about 450 ft. along the fall line to from 850 to 900 ft. along the summit of Parr's ridge. Its principal streams are those that cross the western shore of the Coastal plain and here wind their way from Parr's ridge rapidly toward the south-east in narrow steep-sided gorges and broad limestone valleys. To the west of Parr's ridge the surface for the most part slopes gently down to the east bank of the Monocacy river, and then from the opposite bank rises rapidly toward the Catoctin mountain; but just above the mouth of the Monocacy on the east side of the valley is Sugar Loaf mountain (1,250 feet).

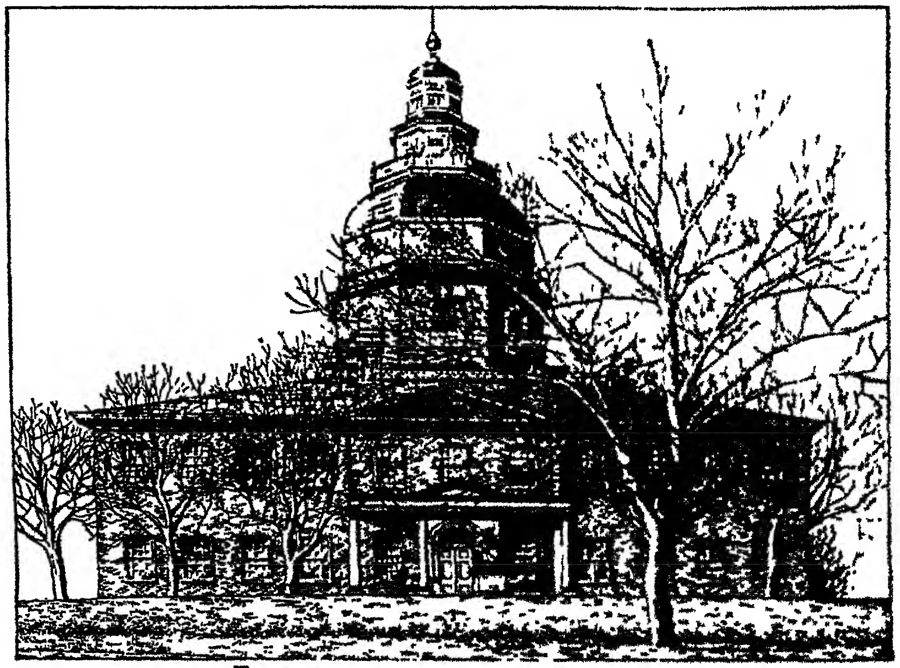
The portion of the State lying within the Appalachian region is commonly known as western Maryland. To the eastward it abounds in mountains and valleys, but in the extreme western portion is a rolling plateau. West of Catoctin mountain (1,800 ft.) is Middletown valley with Catoctin creek running through it from north to south and the Blue Ridge mountains (2,400 ft.), near the Pennsylvania border, forming its west slope. Farther west the serrated crests of the Blue Ridge overlook the Greater Appalachian valley, here 73 m. in width, the broad gently-rolling slopes of the Great Cumberland or Hagerstown valley occupying its eastern and the Appalachian ridges its western portion. Through the eastern portion Antietam creek to the east and Conococheague creek to the west flow in meandering trenches that in places exceed 75 ft. in depth. The Appalachian ridges of the western portion begin with North mountain on the east and end with Wills mountain on the west. They reach a maximum height in Martin's ridge of more than 2,000 feet. Overlooking them from the west are the higher ranges of the Alleghenies among which the Savage, Backbone and Negro mountains reach elevations of 3,000 ft. or more. In the extreme western part of the State these mountains merge as it were into the rolling Appalachian plateau, having an average elevation of 2,500 feet. All rivers of western Maryland flow south into the Potomac except in the extreme west where the waters of the Youghiogheny and its tributaries flow north into the Monongahela, a tributary of the Ohio.

Climate.—The climate of Maryland in the south-east is influenced by ocean and bay, while in the west it is influenced by the mountains. The prevailing winds are westerly but generally north-west in winter in the west section and south-west in summer in the south section. In the south the normal winter is mild, the normal summer rather hot; in the west the normal winter is cold, the normal summer cool. The normal average annual temperature for the entire State is between 53° and 54° F, ranging from 48° at Grantsville in the north-west to 53° at Darlington in the north-east, and to 57° at Princess Anne in the south-east. The normal annual precipitation for the State is about 43 inches.

Soils.—The great variety of soils is one of the more marked features of Maryland. On the eastern shore to the north is a marly loam overlying a yellowish-red clay subsoil, to the south is a soil quite stiff with light-coloured clay, while here and there, especially in central and southern Maryland, are considerable areas both of light sandy soils and tidal marsh loams. On the western shore the soils range from a light sandy loam in the lower levels south from Baltimore to rather heavy loams overlying a yellowish clay on the rolling uplands and on the terraces along the Potomac and the Patuxent. Crossing the State along the lower edge of the fall line is a belt heavy with clay, but so impervious to water as to be of little value for agricultural purposes. The soils of the Piedmont plateau east of Parr's ridge are, like the underlying rocks, exceptionally variable in composition, texture and colour. For the most part they are considerably heavier with clay than are those of the Coastal plain, and better adapted to general agricultural purposes. West of Parr's ridge in the Piedmont the principal soils are those the character of which is determined either by decomposed red sandstone or by decomposed limestone In the east portion of the mountainous region the soil, so well adapted to peach culture, contains much clay together with particles of Cambrian sandstone. In the Hagerstown valley are rich red or yellow limestone-clay soils. The Allegheny ridges have only a thin stony soil but good limestone, sandstone, shale and alluvial soils occur in the valleys and in some of the plateaux of the extreme west.

Government.—The present State Constitution was adopted in 1867 and has been frequently amended, this requiring merely a three-fifths vote of all of the members elected to each of the two houses of the general assembly, followed by a majority of the votes cast when submitted to the State electorate. It is further provided that once in 20 years, beginning with 1930, the wish of the people in regard to calling a convention for altering the Constitution shall be ascertained by a poll. The law provides for direct primary elections.

The chief executive authority is vested in a governor elected by popular vote for a term of four years. Since becoming a State Maryland has had no lieutenant-governor except from 1864 to 1867. The office of governor is to be filled in the case of a vacancy by such person as the general assembly may elect; the president of the senate serving as governor in the meanwhile. No veto power



THE STATE CAPITOL AT ANNAPOLIS

whatever was given to the governor until 1867, when, in the present Constitution, it was provided that no bill vetoed by him should become a law unless passed over his veto by a three-fifths vote of the members elected to each house.

In 1922, in consequence of a plan prepared by Governor Albert C. Ritchie, the administrative branch of the State Government was completely reorganized by consolidating more than 80 State

agencies, according to their functions, into 18 major departments and commissions. This reorganization plan has saved several hundred thousand dollars annually in the operation of the government of the State and the various local subdivisions thereof. A merit system was established for the selection of State employees and in 1936 85% of all State employees were in the classified service.

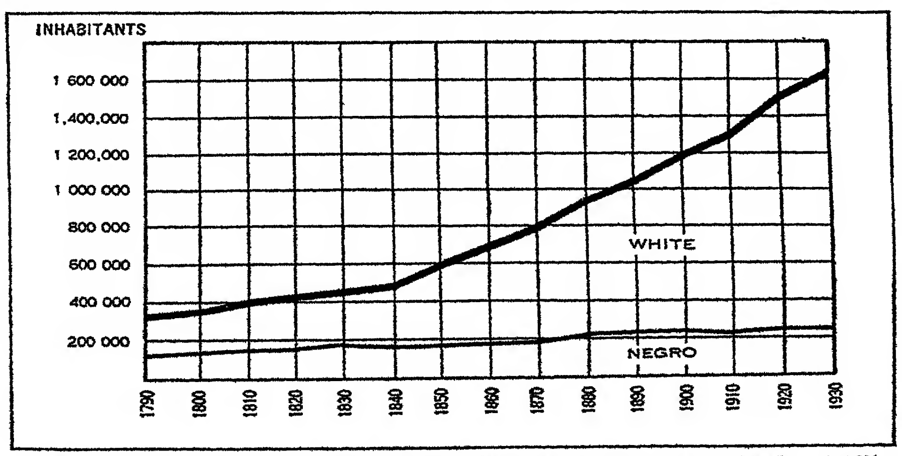
The legislature, or general assembly, meets biennially, on the first Wednesday in January in odd-numbered years, at Annapolis, and consists of a senate and a house of delegates. Senators are elected, one from each of the 23 counties and one from each of the six legislative districts of the city of Baltimore, for a term of four years, the terms of one-half expiring every two years. Delegates are elected for a term of four years.

The administration of justice is entrusted to a court of appeals, circuit courts, special courts for the city of Baltimore, orphans' courts and justices of the peace. Exclusive of the city of Baltimore, the State is divided into seven judicial circuits, in each of which are elected for a term of 15 years one chief judge and two associate judges, excepting the third judicial circuit which elects one chief judge and three associate judges. The seven chief judges so elected, together with one elected from the city of Baltimore, constitute the court of appeals, the governor with the advice and consent of the senate designating one of the eight as chief judge of that court. The court has appellate jurisdiction only.

Finance.—Maryland was one of the first States in the Union to adopt the executive budget to control its finances. A constitutional amendment providing for such a fiscal plan was adopted in 1916. The governor prepares the budget and submits it in the form of a budget bill to the legislature. The legislature can reduce or eliminate appropriation items, but cannot increase them. The bill, when passed by the legislature, fixes appropriations, and becomes a law without the approval of the governor.

The comptroller's report for the year ended June 30, 1932, showed receipts $104,598,518, disbursements $116,869,498, and a balance in the treasury of $12,270,980. The gross debt of the State and all subdivisions, less sinking-fund assets, was $261,167,767. The chief sources of revenue, other than bonds, were: a general direct property tax; the motor licence fees; a motor vehicle fuel tax; a tax on the gross receipts of corporations; an inheritance tax; traders' licences; and franchises on ordinary business corporations. The main expenditures in the order of their importance were: protection to person and property, $1,417,000; highway maintenance, $5,023,000; education, $6,044,000; maintenance of hospitals, homes and asylums, $3,680,000; and for the general government, $2,567,000. On an assessed property valuation of $2,728,734,827 there were levied in 1934 taxes of $6,275,197.

Population.—The population of Maryland at certain selected censuses was as follows: 319,728 in 1790; 341,548 in 1800; 447,-



GRAPH OF GROWTH OF POPULATION IN MARYLAND, 1790—1930, SHOWING RELATIVE PROPORTIONS OF NEGRO AND WHITE AT EACH CENSUS

040 in 1830; 687,049 in 1860; 934,943 in 1880; 1,042,390 in 1890; 1,188,044 in 1900; 1,449,661 in 1920; and 1,631,526 in 1930. Of the total population of the State in 1930 there were 1,354,170 whites, 276,379 negroes and 977 of all other races. Of the whites, 95,093 or 5·8% were foreign-born.

The population of those cities in Maryland having in 1930 more than 12,000 inhabitants was as follows.

	1930	1920	1910
Baltimore	804,874	733,826	558,485
Cumberland	37,747	29,837	21,839
Hagerstown	30,861	28,064	16,507
Annapolis	12,531	11,214	8,609
Frederick	14,434	11,066	10,411

The Roman Catholic Church, which was prominent in the early history of Maryland, has the greatest membership. Other denominations in the order of their numerical strength are: Methodist Episcopal; Protestant Episcopal; Lutheran, General Synod; Baptist; Methodist Protestant; and Presbyterian.

Charities and Corrections.—State institutions controlled by boards appointed by the governor comprise two penal institutions, the Maryland Penitentiary in Baltimore and the Maryland House of Correction at Jessups; a training school for boys and another for girls, one for feeble minded and one for the deaf; three hospitals for white insane, Eastern Shore State Hospital at Cambridge, Springfield State Hospital at Sykesville, and Spring Grove State Hospital at Catonsville, and one for coloured, Crownsville State Hospital at Crownsville; two general hospitals and four tubercular hospitals, three for white, State Sanatorium in Frederick County, Eastern Shore Branch at Salisbury and Mt. Wilson Branch, and a coloured branch at Henryton. The State-aided institutions include a school and workshop for the blind, reformatories for coloured boys and girls, tuberculosis sanatoria, homes for children and the aged, schools, colleges and hospitals.

Education.—A completely revised code of school laws was passed by the legislature of 1916, supplanting the common-school system established by the act of 1865. At the head of the educational system is a State board of seven lay members appointed by the governor. This board elects the State superintendent for a term of four years.

The State's population between the ages of 5 and 17, inclusive, was 407,500 in 1932. The enrolment in the public schools was 288,169 (235,967 being in the elementary and 52,202 in the secondary schools).

The University of Maryland was enlarged in 1920 by an act of the legislature merging the University of Maryland, comprising the schools of law, medicine, pharmacy and dentistry at Baltimore, the Maryland State college, formerly known as Maryland Agricultural college, at College Park, and the eastern branch of the university, for coloured students, at Princess Anne. The State board of agriculture and the State horticultural department are also connected with the university.

Johns Hopkins university (*q.v.*), Baltimore, which was established from a fund of nearly $7,000,000 left by Johns Hopkins, upon his death in 1873, for the purpose of founding a university and a hospital, is one of the leading educational institutions of the United States. Other institutions of higher learning in the State, with the names of such religious bodies as were originally responsible for them, are: St. John's college, at Annapolis; Washington college, at Chestertown; Western Maryland college (Methodist Protestant), at Westminster; Mount St. Mary's college (Roman Catholic), at Emmitsburg; St. Mary's seminary and Loyola college (Roman Catholic), at Baltimore; Hood college (Reformed Church), at Frederick; Goucher college (Methodist), at Baltimore; the U.S. Naval academy, at Annapolis; and several professional schools, mostly in Baltimore. Other institutions of an educative character in Baltimore are Peabody Conservatory of Music (established in 1866); Maryland Institute for the Promotion of Fine and Mechanic Arts; and Enoch Pratt free library (established 1886).

Public Health.—The State board of health of eight members consists of the attorney general of the State, health commissioner of Baltimore and six members appointed by the governor, with

the consent of the senate. Of those appointed by the governor, four are physicians, one a civil engineer and one a certified pharmacist. The governor designates one of the four physicians as chairman who thereby becomes director of health. The gross death rate for the State in 1933 was 12·4 per 1000. Births numbered 27,340 in 1934, and deaths 20,946.

Agriculture.—Agriculture is an important industry in Maryland, and statistics show that the average yields of all the staple crops have increased. There has also been a tendency towards smaller sized farms, cultivated more intensively for the production of food for human consumption, such as vegetables, fruits, dairy products, butter, eggs and meats. The soils and climate of Maryland are well suited to this class of products, and there are good transportation facilities for reaching the big centres of population in the eastern States.

The land area of the State is 6,362,240 ac., of which 4,383,641 is in farms. This is divided into 44,412 farms; 73·6% of these are operated by the owners. White farmers operated 39,518 farms and coloured farmers 4,894. The total value placed on all farm property within the State in 1935 was $242,714,142.

The following table presents some detailed figures concerning the principal agricultural products for the year 1934:

	Acreage	Production
Wheat	407,578	7,613,920 bu.
Indian corn	451,207	13,104,956 bu.
Oats	54,276	1,085,716 bu.
Hay	396,380	528,340 tons
Tobacco	36,381	24,798,728 lbs.
Irish potatoes	33,547	3,404,271 bu.
Sweet potatoes and yams	7,379	949,981 bu.

The value of the principal classes of live stock, horses, mules, cattle, sheep and swine on Jan. 1, 1935 was $22,791,655, dairy cattle being the most numerous. There were produced in 1929, 87,786,000 gals. of milk and 3,626,000 lb. of butter.

The live stock, wheat and Indian corn sections of the State are in the Piedmont plateau, the Hagerstown valley and the central portion of the eastern shore. Garrett county, in the extreme north-west, however, raises the largest number of sheep. Most of the tobacco is grown in the southern counties of the western shore. The great centre for vegetables and small fruit is in the counties bordering on the north-west shore of the Chesapeake, and in Howard, Frederick and Washington counties.

Sea Foods and Game.—The conservation department has full supervision and control over all the natural resources of the State, including oysters, crabs, fish, clams and terrapin, as well as wild fowl, birds and game. In 1934, 7,676 persons were engaged in the fishing industry. The production in 1933 was 55,362,000 lb., valued at $1,733,800. During 1934–35 there was produced 2,601,066 bu. of oysters, 13,620,900 lb. of hard crabs, 2,288,800 lb. of soft crabs, 5,233,400 lb. of alewives, 2,131,000 lb. of croaker, 1,485,600 lb. of squeteagues and 885,300 lb. of shad.

Garrett, Allegany and western Washington counties furnish the home for the wild turkey, white-tailed deer and the ruffed grouse. Bob-white quail, cottontail rabbit and the gray squirrel are found in every county. On the Chesapeake bay and its tributaries practically every species of wild duck that migrates east of the Mississippi river is to be found.

Forests.—Maryland's forest resources consist of 2,228,000 ac. of woodland, or nearly 35% of the total land area of the State. Less than 2% of this area is virgin forests,—practically all of the woodlands having been cut over one or more times. The lumber production for the year 1933 was 12,000,000 board feet.

There are over 150 different species of trees, most of them of commercial importance, embracing the yellow pine, cypress, cedar and red gum in the south-western part of the State, and spruce, white pine, hemlock, beech, birch and maple in the mountains.

The State maintains a forestry department, whose chief functions are to provide a system of forest protection; give assistance to woodland owners in the management of their forest properties; administer the six State forests (about 5,000 ac.) and the State forest nursery; and care for trees along all public highways.

Minerals.—In 1929, the product of 130 mines and quarries in the State, employing 4,978 persons, was $11,122,195. The principal products in the order of their value were coal ($4,745,279), sand and gravel ($3,780,937), limestone ($1,053,738), basalt ($599,034), marble and slate ($334,018) and granite ($261 259). The coal-producing area is confined to the counties of Allegany and Garrett. There are five or six workable seams of coal, the most important being the Big Vein which is correlated with the Pittsburgh coal of western Pennsylvania. In 1934, there were mined 1,627,112 net tons of coal, most of which was burned in byproduct ovens which produced 784,539 net tons of coke.

Maryland building stone, of which there is an abundance of good quality, consists chiefly of granites, limestones, slates, marble and sandstones, the greater part of which is quarried in the east section of the Piedmont plateau though some limestones, including those from which hydraulic cement is manufactured and some sandstones are obtained from the western part of the Piedmont plateau and the east section of the Appalachian region. Brick, potter's and tile clays are obtained most largely along the west border of the coastal plain, and fire clay from the coal region of western Maryland. Materials for porcelain including flint feldspar and kaolin, are found in the east portion of the Piedmont plateau.

Transportation.—There were 3,884 m. of modern roadway all of which are maintained in excellent condition throughout the year. In 1933, 110 m. of new construction was completed.

Tidewater Maryland is afforded very unusual facilities of water transportation by the Chesapeake bay, with its deep channel, numerous deep inlets and navigable tributaries, together with the Chesapeake and Delaware canal, which crosses the State of Delaware and connects the Chesapeake bay with the Delaware bay. Baltimore (*q.v.*), was the second foreign trade port of the United States in 1936. It also has a great inter-coastal traffic especially with the Pacific ports. Baltimore is the railway centre of the State, and it was here in Feb. 1827 that the Baltimore and Ohio, one of the first railroads in the United States, was projected. In 1935, in Maryland there were 1 430 m. of steam railway under operation.

Manufacturing.—Manufacturing is by far the State's chief industry and is constantly increasing in importance. The number of persons engaged in manufacturing in [illegible] was [illegible]; and in 1933, 100,236. The total value of manufactures in 1914 was $[illegible]-749,078, in 1925 $926,251,640, and in 1933, $[illegible]. Of the 1925 production, $678,947,199, and of 1933 production $[illegible],301 were the product of plants in the Baltimore area. In the period 1914–25, the value of Maryland's manufactures advanced 145·2%. The following table shows the value of the products of the leading industries in 1925, with the two exceptions noted:

Products	Value
Men's clothing	$[illegible]
Iron and steel, steel works and roller mills	[illegible]*
Slaughtering and meat packing	[illegible]
Petroleum refining	[illegible]*
Canning and preserving fruit and vegetables	[illegible]
Fertilizers	[illegible]
Printing and publishing	[illegible]
Tinware	[illegible]
Car and general shop construction and repairs, for steam railways	[illegible]
Foundry and machine shop products	[illegible]

*1923 figures.

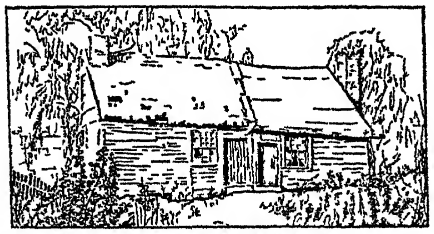
According to the U.S. Census of Manufactures for 1933 the value of men's clothing manufactured the previous year was $25,-100,000. Slaughtering and meat packing products were valued at $18,956,000, canning products at $21,624,000, fertilizers at $12,-611,000, printing and publishing products at $8,684,000 and tinware at $21,400,000. The cost of car and general shop constructions and repairs for steam railways was $8,589,000.

Baltimore's industries are widely diversified with no single line employing over 10% of the city's industrial workers." There are 26 classifications, each of which before the depression employed over 1,000 men.

HISTORY

In the year 1632 King Charles I. granted a charter to George Calvert, first Lord Baltimore (*c.* 1580–1632), conveying to him almost unlimited territorial and governmental rights in a tract of land between the Potomac river and the 40th parallel, and styling him absolute lord and proprietor thereof. Subsequent clauses of the charter so circumscribed the proprietor's power that, in effect, it differed little from other colonial patents granted by Charles I. George Calvert died before the charter had passed the Great Seal and, in the same year, the charter was issued to his oldest son, Cecil. In Nov. 1633, two vessels, the "Ark" and the "Dove," carrying at least 200 colonists under Leonard Calvert, a brother of the proprietor, as governor, sailed from Gravesend. They arrived in Maryland late in March of the following year, and the colonists established a settlement on a promontory between the Potomac river and the Chesapeake bay. For several years their relations with the Indians were friendly, but eventually the colony suffered severely from Indian wars. More serious was the hostility of William Claiborne (*c.* 1589–1676), secretary of the Colony of Virginia, who, under a trader's licence, had purchased Kent island in the Chesapeake bay from the Indians and had in 1631 established a settlement there. As a result of Claiborne's refusal to recognize the jurisdiction of Lord Baltimore over Kent island, in which he was supported by the council of Virginia, an enmity developed between him and Leonard Calvert which resulted in a long feud between the Maryland settlers and Claiborne's men, marked by continual attacks and reprisals. The Colony enjoyed peace from 1660 until 1688.

The province of Maryland presented an early and successful example of tolerance toward the religious beliefs of its inhabitants. Lord Baltimore was a Roman Catholic, and probably it was his intention that Maryland should be an asylum for persecuted members of that body. He desired Protestant colonists also, however, and to this end promised and, so far as he could, established and enforced religious toleration in its full sense. With the growth of a Puritan party in the province, fearing that he would soon lose control of affairs, he proposed to the assembly the famous act concerning religion which was passed in 1649. It extended tolerance and protection only to bodies professing trinitarian Christianity, and was thus somewhat less liberal than the policy which the proprietor had earlier pursued.


BY COURTESY OF MARKEN & BIELFELD, INC.
OLD HOUSE IN FREDERICK, MD., LOCALLY KNOWN AS WASHINGTON'S HEADQUARTERS

Although the charter reserved to the proprietor the right of calling an assembly of the freemen or their delegates when and as he should choose, the colonists obtained from him in 1638 the surrender of his claim to the sole right of initiating legislation. This is one of the most striking examples of the effort to secure local self-government shown in any of the 13 Colonies. By 1650 the assembly had been divided into two houses. One of these, the consent of which was necessary before a bill might become law, was composed entirely of the representatives of the freemen, and annual sessions as well as triennial elections were becoming usual. In 1670 the governor, Charles Calvert, sought to check growing opposition to his policy by disfranchising all freemen who did not have a freehold of 50 ac. or a visible estate of £40 sterling. This step caused impassioned complaints against him in which it was alleged that he was interfering in elections and keeping the government in the hands of Roman Catholics, mostly members of his own family. About this time also the northern and eastern boundaries of the province began to suffer from the encroachments of William Penn. The territory now forming the State of Delaware was within the limits defined by the Maryland charter, but in 1682 it was transferred to Penn by the Duke of York, and in 1685 Lord Baltimore's claim to it was denied by an order in council on the ground that it had been inhabited by Christians before the Maryland grant was made. Later a controversy over the northern boundary arose. Although Cecil Calvert's patent specified the parallel of 40° N. as the northern boundary of his grant, Penn's charter set forth that Pennsylvania should extend southward to the "beginning of the fortieth degree of Northern Latitude." A difference of interpretation of this expression led to much litigation which was not settled until Charles Mason and Jeremiah Dixon, English mathematicians, between 1763 and 1767, established the line, since named after them, which followed the parallel 39° 43′ 26·3″.

While the proprietor was absent defending his claim against Penn, the English Revolution of 1688 occurred. Owing to the death of a messenger, proclamation of the new monarchs in Maryland was long delayed and this, together with a rumour of a Popish plot to slaughter Protestant colonists, caused the overthrow of the proprietary government. In 1692 the Crown, in the interests of trade, set up a royal government but permitted the proprietor to retain his territorial rights. Under government by the Crown the Church of England was established. When a Protestant became heir to the proprietorship in 1715, proprietary government was restored. Roman Catholics were disfranchised.

The first serious dispute between proprietor and colonists after the restoration of 1715 concerned the extension of the English statutes to Maryland. The popular chamber of the assembly contended that all such statutes except those expressly excluded extended to the province, and the lord proprietor insisted that only those in which the dominions were expressly mentioned were in force there. Other disputes followed; and when France and England joined in a final struggle for territory in America, a deadlock between the two houses of the assembly prevented Maryland from responding to urgent appeals from England for help in the closing stage of the war.

In the years immediately preceding the Declaration of Independence, the practice of self-government became so intensely an ideal of the people of Maryland that on occasion they offered resistance not only to the proprietary, the royal governor, parliament and the king, but also to what they considered the unwarrantable encroachments of the Continental Congress. Maryland was not, however, actually invaded or physically oppressed by the British, and probably for that reason the instructions to her delegates to the Continental Congress, bidding them not to vote for independence, were left unchanged until the Colony found itself almost alone in holding back. The new Constitution drawn and adopted in 1776 to replace the royal charter was far from democratic in character. By its provisions the property qualification for suffrage was a freehold of 50 ac. or £30 current money; the property qualifications for delegates £500, for senators £1,000, and for governor £5,000. Four delegates were chosen from each county and two each from Annapolis and Baltimore. In 1802 negroes were enfranchised. In 1810 property qualifications for suffrage were abolished. With the growth of the city of Baltimore, the prevailing disproportionate representation began to be attacked, but the slave-holding minority in the counties of southern Maryland, fearing the attitude of the majority toward slavery, prevented any change until 1837. In that year the enthusiasm over internal improvements enabled the opposition to obtain the adoption of amendments which provided for the election of the governor and senators by direct vote of the people, a slight increase in the representation accorded the city of Baltimore and the larger counties, and a slight decrease in that of the less populous. Serious financial straits caused by debt incurred through the State's promotion of internal improvements caused a demand for the limitation of the power of the assembly to contract debts. The result was the Constitution of 1851 which established proportional representation for the counties and increased the number of delegates from Baltimore. This was, however, an unsatisfactory compromise. When, during the Civil War, Maryland was largely under Federal control and a demand arose for the abolition of slavery by the State, a constitutional convention held in 1864 framed a Constitution disfranchising all those who had given aid to the rebellion, and allowing only those possessing the suffrage under the proposed instrument to vote on its adoption.

This was too ill-considered to endure, and in 1867 it was superseded by the present Constitution.

In national affairs Maryland, at an early date, took a stand which had far-reaching consequences. Her delegates refused to sign the Articles of Confederation until the States claiming territory between the Allegheny mountains and the Mississippi and north of the Ohio—Virginia, New York, Massachusetts and Connecticut—should surrender their claims. Her opposition caused those States to yield, and strengthened the Union because it brought into the possession of the United States the first territory in which all the States had a common interest and out of which new States could be created. In the War of 1812 Havre de Grace and Frenchtown were burned by the British, but Baltimore was successfully defended at North Point against a formidable attack by a British army, and a strong British fleet failed to reduce Fort McHenry after a bombardment of 24 hours. The latter event inspired Francis Scott Key, who was detained aboard a British vessel, to compose "The Star-Spangled Banner."

In 1861 Maryland was divided on the question of secession, the southern and eastern parts generally favouring the cause of the seceding States; but the majority in the northern and western counties, as well as the fact that the State lay north of Washington and quickly came under the control of the Federal Government, kept the State from joining the Confederacy. Maryland was, however, opposed to coercing the seceded States. Maryland was twice invaded by Southern armies, but the only battle of importance fought on her soil was that of Antietam or Sharpsburg on Sept. 16 and 17, 1862.

Since the Civil War, the State's history is a record of quiet but steady progress. A boundary dispute of more than 200 years duration was settled in 1879 when Maryland and Virginia agreed to accept the award of a commission of arbitrators. Possibly the greatest disaster that ever befell the State occurred in Feb. 1904, when a fire destroyed the business district of Baltimore, burning more than 1,300 buildings in the heart of the city. But a new and modernized city soon appeared.

The State was in the forefront of World War activities, from the time the United States declared war on April 6, 1917. The total contribution by the State to the military and naval forces of the United States was about 63,000: approximately 52,000 to the army, 10,000 to the navy and 1,200 to the marine corps.

In 1930 the age-old dispute between Maryland and Virginia over the boundary along the bed of the lower Potomac river and adjacent waters was settled in accordance with the findings of two investigators, appointed by the governor of each State. The boundary was set to run from headland to headland, touching in each case the low-water mark on the Virginia shore. Various attempts had been made to settle this dispute since the early days of the colonies. In view of the value of the submerged lands as oyster beds it had become known as "the oyster war."

As between political parties, from 1820 to 1860 the Whigs were dominant, while from 1866 until 1934 Democrats enjoyed control except for two brief periods. Roosevelt carried the State by a 5 to 3 vote in 1932; but Governor Ritchie was defeated for a fifth term in 1934 by his Republican rival, Harry W. Nice.

In 1933, the Maryland legislature ratified the Twenty-First Amendment repealing Federal prohibition, the popular vote of the State having favoured such action by 5 to 1. On May 30, 1934, there was observed in Baltimore the three hundredth anniversary of the founding of Maryland.

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The best source of ready information respecting the State's officials and governmental organization is *The Maryland Manual, A Compendium of Legal, Historical and Statistical Information* (yearly). Other sources are the *Annotated Code of Public Civil Law*; the *Industrial Directory* of the State board of labour and statistics; and the reports of the State board of education, the treasurer and the public utility commission. *The Fifteenth United States Census*, the 1933 *Census of Manufactures* and the 1935 *Census of Agriculture* contain statistical information regarding the State. The physical features and economic sources are treated in the *Publications of the Maryland Geological Survey* (1897 *et seq.*). In the latter are also historical studies of the Baltimore-Penn controversy leading to the Mason & Dixon line. *See* also *Old Maps and Map Makers* and *County Boundaries* by E. B. Mathews. (A. C. R.)

MARYLEBONE, ST., commonly MARYLEBONE (mă'rĭ-bŏn), a north-western metropolitan borough of London, bounded north by Hampstead, east by St. Pancras and Holborn, south by the City of Westminster and west by Paddington. Pop. (1931) 97,620. The boundary runs along Oxford Street, on the south, crossing Regent Street at Oxford Circus, and Edgware Road on the west; Marylebone Road crosses from east to west. St. Marylebone was in the manor of Tyburn, which takes name from the Tyburn, a stream which flowed south to the Thames through the centre of the present borough. The church was called St. Mary at the Bourne. The name Tyburn (*q.v.*) was notorious chiefly as applied to the gallows which stood near the existing junction of Edgware Road and Oxford Street (Marble Arch). The manor at the Domesday Survey was in the possession of the nunnery at Barking, but the borough includes several estates, such as the manor of Lyllestone in the west, the name of which is preserved in Lisson Grove. From 1738 to 1776 Marylebone Gardens (which had existed under other names from the close of the 17th century) became one of the most favoured evening resorts in London. They extended east of High Street as far as Harley Street, but by 1778 the ground was being built over.

The borough includes almost the whole of Regent's Park, with a portion of Primrose Hill north of it. The park originally Marylebone Park, was enclosed by James I., and received its modern name from the Prince Regent, afterwards George IV. It contains the Zoological Gardens. Here are also the gardens of the Royal Botanic Society, incorporated in 1839. The Toxophilite Society, founded in 1781, has also occupied grounds here since 1883. Another famous enclosure is Lord's Cricket Ground, St. John's Wood Road. Marylebone station is a terminus of the L.N.E.R. The borough returns one member to parliament. Area 1,473 acres.

MARY OF LORRAINE (1515–1560), generally known as MARY OF GUISE, queen of James V. and afterwards regent of Scotland, was born at Bar on Nov. 22, 1515. She was the eldest child of Claude of Guise and Antoinette of Bourbon, and married in 1534 Louis II. of Orleans, duke of Longueville, to whom in 1535 she bore a son, Francis (d. 1551). The duke died in 1537, and Mary was sought in marriage by James V., and by Henry VIII. after the death of Jane Seymour. Henry persisted in his offers after her betrothal to James V. Mary, who was made by adoption a daughter of France, married James at St. Andrews. Her two sons, James (b. May 1540) and Robert or Arthur (b. April 1541), died within a few days of one another in April 1541, and her husband died in Dec. 1542, within a week of the birth of his heiress, Mary, Queen of Scots. The regency fell to the heir presumptive James, earl of Arran, who favoured England and the Protestant party, and who hoped to secure the infant princess for his son.

Mary of Lorraine was approached by the English commissioner, Sir Ralph Sadler, to induce her to further her daughter's marriage contract with Edward VI. The marriage treaty between Mary, not then one year old, and Edward was signed in July at Greenwich, and guaranteed that Mary should be placed in Henry's keeping when she was ten. (*See* MARY QUEEN OF SCOTS.)

In 1550 Mary of Lorraine visited France and obtained from Henry II. the confirmation of the dukedom and revenues of Châtelherault for the earl of Arran, in the hope of inducing him to resign the regency. Arran refused to relinquish the regency until 1554, when he resigned after receiving an assurance of his rights to the succession. Mary had now to deal with an empty exchequer and with a strong opposition to her daughter's marriage with the dauphin. The first revolt against her authority arose from an attempt to establish a standing army. When she provoked a war with England in 1557 the nobles refused to cross the border. In matters of religion she tried to hold the balance between the Catholics and Protestants and allowed the Presbyterians the practice of their religion so long as they refrained from public preachings in Edinburgh and Leith, but the marriage of Francis II. and her daughter Mary in 1558 strengthened her position, and in 1559 she adopted the religious policy of her relatives, the Guises. She was reconciled with Archbishop Hamilton, and took up arms against the Protestants of Perth, who, incited by Knox, had destroyed the Charterhouse with the royal tombs. They submitted on condition that no foreign garrison was imposed on Perth and that the religious questions should be brought before the Scottish parliament. Mary of Lorraine broke the spirit of this agreement by garrisoning Perth with Scottish troops in the pay of France. The lords of the Congregation soon assembled in considerable force on Cupar Muir. Mary retreated to Edinburgh and thence to Dunbar, while Edinburgh opened its gates to the reformers, who issued a proclamation (Oct. 21, 1559) claiming that the regent was deposed. The lords of the Congregation sought help from Elizabeth, while the regent had recourse to France. The strength of her opponents was increased by the defection of Châtelherault and his son Arran, and by the betrayal of her plans by her secretary Maitland to the lords of the Congregation. In Oct. 1559 they made an unsuccessful attack on Leith. Mary entered Edinburgh and conducted a campaign in Fife.

When an English army under Lord Grey entered Scotland in March 1560, the regent received an asylum in Edinburgh castle, which was held strictly neutral by John Erskine. Before her death (June 11, 1560) Mary sent for the lords of the Congregation, with whom she pleaded for the maintenance of the French alliance. She was buried in the church of the nunnery of St. Peter at Reims.

The chief sources for her history are the Calendar of State Papers for the reigns of Henry VIII. and Edward VI. in the Rolls Series; A. Teulet, *Papiers d'état . . . relatifs à l'histoire de l'Ecosse au XVIe siècle* (3 vols., 1851), for the Bannatyne club; *Hamilton Papers*, ed. J. Bain (2 vols., 1890–99); *Calendar of State Papers relating to Scotland and Mary Queen of Scots, 1547–1603* (2 vols., 1898–1900), etc. The Life in Miss Strickland's *Queens of Scotland* (vols. i.–ii.) is based on original documents. Miss M. Wood has edited *The Foreign Correspondence with Marie de Lorraine, Queen of Scotland* (2 vols., 1923 and 1925) and Miss A. I. Cameron has edited *The Scottish Correspondence of Mary of Lorraine* (1927).

MARY OF MODENA [MARIA BEATRICE ANNE MARGARET ISABEL D'ESTE] (1658–1718), queen of the English king James II., and daughter of Alphonso IV., duke of Modena, and the Duchess Laura, of the Roman family Martinozzi, was born at Modena on Oct. 5, 1658. She was married by proxy to James, then duke of York, on Sept. 30, 1673, and in November reached England where she was regarded as an agent of the pope. During the Popish Plot, she went abroad with her husband. When her son, James Francis Edward, was born on the 10th of June (o.s.) 1688, it was said that the child was not really hers, and that a fraud had been perpetrated to secure a Roman Catholic heir. At the outbreak of the revolution she made the disastrous mistake of consenting to escape to France (Dec. 10, 1688) with her son. She urged her husband to follow her when it was his manifest interest to stay in England, and when he went to Ireland she pressed for his return. Her daughter, Louisa Maria, was born at St. Germain on June 28, 1692. When her husband died on Sept. 6, 1701, she induced King Louis to recognize her son as king of England, an act which precipitated the war of the Spanish Succession. Surviving her husband for 17 years, Mary lived at St. Germain or at Chaillot, in a house of the Visitation, where she eventually died on May 7, 1718.

See Miss Strickland, *Queens of England* (vols. 9 and 10, 1846); Campana di Cavelli, *Les Derniers Stuarts à Saint-Germain en-Laye* (London, 1871); and M. Haile *Mary of Modena* (1905).

MARYPORT, a market town and seaport in Cumberland, England, 25 m. W.S.W. of Carlisle, on the railway. Pop. of urban district (1931) 10,182. It is built on the shore of the Irish sea, at the mouth of the river Ellen. Before the harbour was built there in 1750 Maryport consisted of a few huts. In 1892 Maryport became an independent port with Workington, Whitehaven and Millom subordinate to it. On the hill north of the town is the Roman fort of Uxellodunum.

MARYSVILLE, a city of north-central California, U.S.A., on the Yuba river, near its confluence with the Feather, 47 m. N. of Sacramento; the county seat of Yuba county. It is served by the Sacramento Northern (electric), the Southern Pacific and the Western Pacific railways, and by auto-stage and motor-truck lines. Pop. 5,461 in 1920; in 1930, 5,763 by Federal census. A mile west is Yuba City (pop. in 1928 estimated at 3,400), the county seat of Sutter county. Marysville is the commercial, educational and social centre of a productive fruit-growing region, specializing in clingstone peaches, pears, prunes and grapes. Settlement dates from 1842, when Theodore Cordua leased from Gen. John A. Sutter the present site of Marysville and established a trading post. In the days of '49 it became an important town, as it was at the head of river traffic to the mines and on the trail running north and south through the Sacramento valley. For several years 30 or 40 stages arrived and departed daily, and large pack trains carried supplies into the mountains. The present name was adopted in 1850, in honour of the wife of one of the settlers.

MARYVILLE, a city of north-western Missouri, U.S.A., on Federal highway 71, and served by the Burlington and the Wabash railways; the county seat and commercial centre of Nodaway county and the seat of the North-west Missouri State Teachers college. Pop. 4,711 in 1920; and 5,217 in 1930. The city was settled in 1845 and incorporated in 1856. Since 1919 it has had a commission-manager form of government.

MASACCIO, properly TOMASO GUIDI (1401–*c.* 1428) Florentine painter, born on Dec. 21, 1401, at Castel S. Giovanni di Val d'Arno, near Florence, son of a notary of the family of the Scheggia, was nicknamed Masaccio (for Tomasaccio) on account of his careless habits. In 1422 he was enrolled in the guild of Speziali, or druggists, to which painters belonged, and in 1424 in the guild of St. Luke. He was one of the great pioneers of the Italian Renaissance who did for painting what Donatello had done for sculpture and Brunelleschi for architecture.

With the work of Masaccio began the search for the rendering of three dimensional space and for the placing therein of figures plastically conceived. The newly-discovered laws of perspective were applied, the drawing of foreshortened parts was correct, the anatomy of the human body was well understood. According to Vasari, Masaccio owed his artistic education to Masolino, but Masaccio, although he died 20 years before his master, carried the advance in naturalism further. Unfortunately much of his work has been destroyed, and what remains is often in poor condition. His earliest extant works are the "St. Anne, the Virgin and Child," removed from the Church of S. Ambrogio to the Uffizi; and a fresco of the "Virgin Enthroned Between Two Saints" in the Oratorio of Montemarciano, near his birthplace. On Feb. 19, 1426, he was commissioned to paint an altarpiece for the Church of the Carmine at Pisa by the notary, Giuliano di Colino degli Scarzi. This work had disappeared in 1750. It is described by Vasari, and portions of it have recently been identified. The Berlin museum possesses three pieces of the predella, the "Epiphany," the "Death of the Baptist," and the "Crucifixion of St. Peter," also "Four Saints," which formed part of the framework and were formerly in

e Butler Collection, London. The Museo Civico at Pisa has a ›t. Paul," and at Vienna there is a "St. Andrew," the Naples mu-um has a "Crucifixion," the central panel, representing a "Ma-›nna and Child with Angels," was said by Berenson to be a pic-ıre in the possession of Canon Sutton of Brant Broughton, Lin-›ln, from whom it was bought for the National Gallery. Masac-o's once much admired fresco of the Trinity is to be seen in a ›ery damaged condition on the entrance wall of S. Maria Novella : Florence. Originally painted over the altar of St. Ignatius, it ›as for a long time covered over with a painting of Vasari, and ıen brought to light again. The artist's standard work is in the ›rancacci chapel in the Carmine at Florence. Here Masolino had ›ft unfinished a series of frescoes which Masaccio was asked to ontinue. Six paintings can be ascribed to him with certainty. They represent the "Expulsion from Eden," an expressive painting ›here Eve cries aloud in anguish while Adam covers his face; Peter and the Tribute-Money," a large and harmonious compo-ition; "Peter and John Healing the Sick"; "Peter Almsgiving" ›nd "Peter Baptizing"; the "Raising of the King's Son," in which he saint and the group on the left are in part by him, the re-nainder being by Filippino Lippi. These frescoes created a sensa-ion; they became the training school of Florentine painters of the ›ucceeding generations, of Michelangelo with the rest. Masaccio lid not complete the decoration of the chapel. In 1428 he left for Rome, and was reported dead soon afterwards.

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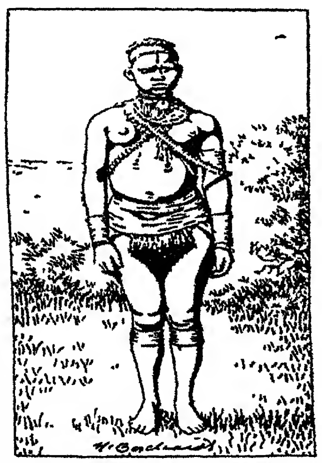
MASAI. The most important members of the Nilo-Hamitic group are the Masai, Nandi, Keyo, Suk, Turkana, Iteso, Kara-mojong, Dodoth, Didinga, Topotha and Ajie. While they are, generally speaking, homogeneous the following distinctions have to be noted: 1. The Suk and the tribes to the south and east, the Masai, the Nandi and their neighbours, practise circumcision and clitoridectomy, while the tribes north of the Suk do not. 2. The Masai, Turkana and Ajie are nomadic; the Nandi, Keyo and Iteso are sedentary and have adopted agriculture in addition to the pastoral life; the rest are semi-nomadic.

The Masai are a tall, well-built, slender people with good features and well-defined noses. The two lower incisors are removed. The heads of the women are shaved, as are the heads of married and of uninitiated men. The warriors wear their hair plaited into queues hanging down the back and over the forehead. The women are scrupulously clothed from girlhood to old-age with dressed skins and leather petticoats. Beads, metal armlets, necklets and bracelets, are popular with both sexes.



BY COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY

A GIRL OF THE MERU-MASAI TRIBE, IN EAST AFRICA

Their dwellings are of a peculiar type, long, continuous houses (not more than 6ft. in height) which are built round the inside of a circular thorn fence. They are flat roofed and are divided into separate compartments for families, each with a door. During their period of service the warriors, who may not yet marry, live in separate barracks or villages, where they are visited by the unmarried girls. The Masai keep cattle (of the humped Zebu type), sheep and goats, donkeys and dogs, and the cattle cult is a feature of their culture. Domestic animals are branded with the brand of their owner's clan. Women and old men eat flour and vegetables in addition to the milk, blood and meat which form the staple diet of the tribe. An intoxicating honey mead is drunk by old men, and all except the warriors smoke tobacco and use snuff. Their weapons are spears (both broad- and narrow-bladed), clubs and a peculiar sword.

The Masai are divided into a number of patrilineal, exogamous clans grouped into four endogamous sections, and inheritance is normally to the eldest son who has to support his father's wives and his own brothers and sisters.

The system of initiation and age-grades (*q.v.*) is the basic feature of Masai social life and has produced a most effective military organization. The tribe is divided into young men or boys and groups of initiated men who pass through successive stages as warriors and elders, differentiated by duties, privileges and details of costume. The centre of political gravity is with the warrior class and there are no chiefs. The elders, whose ranks are replenished by time-expired warriors, act as advisers and with the tribal magician form the judicial and legislative authority, but the executive authority remains with the warriors. The magician (*ol-oiboni*), a hereditary office, is the chief adviser.

BY COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY

THE SON OF A MERU CHIEF WITH HUNTING WEAPONS

Religion is a mixture of ancestor-worship and the worship of *Engai*, the "sky." (Other members of the group have substituted different natural phenomena for *Engai*. The Nandi, for instance, worship *Asis*, the "sun"; the Suk, *Torotut*, the "thunder"; the Didinga, *Tamukunan*, the "rain.") The ancestor cult is associated with certain trees, notably the fig, and with a reverence for snakes, the python and cobra predominating. These are considered tutelary beings, and at marriage a man is careful to introduce his bride to his tutelary snake.

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MASANIELLO, an abbreviation of TOMMASO ANIELLO (1622–1647), an Amalfi fisherman, who became leader of the revolt against Spanish rule in Naples in 1647. A revolt broke out at Palermo in May 1647, and the people of Naples followed the example of the Sicilians. The immediate occasion of the latter rising was a new tax on fruit, the ordinary food of the poor, and the chief instigator of the movement was Masaniello, who led the malcontents. On July 7, 1647 there was a riot at the city gates between the fruit-vendors of the environs and the customs officers, and the customs office was burnt. The rioters then poured into Naples and forced their way into the palace of the viceroy, the hated Count d'Arcos, who fled.

Masaniello was elected "captain-general," and the revolt was even spreading to the provinces. On July 13, through the mediation of Cardinal Filomarino, archbishop of Naples, a convention was signed between D'Arcos and Masaniello as "leader of the most faithful people of Naples," by which the rebels were pardoned, the more oppressive taxes removed, and the citizens granted certain rights, including that of remaining in arms until the treaty should have been ratified by the king of Spain. Masaniello was murdered while haranguing a mob in the market-place on July 16, 1647.

Masaniello's insurrection formed the subject of several operas, of which the most famous is Auber's *La Muette de Portici* (1828).

See Saavedra, *Insurreccion de Napoli en 1647* (2 vol., Madrid, 1849); A. von Reumont, *Die Carafa von Maddaloni* (2 vols., Berlin, 1849); Capasso, *La Casa e famiglia di Masaniello* (Naples, [illegible]); V. Spinazzola, *Masaniello e la sua famiglia, secondo un codice bolognese del sec. xvi.* (in the review *Flegrea*, 1900); A. G. Meissner, *Masaniello* (in German); E. Bourg, *Masaniello* (in French); F. Palermo, *Documenti diversi sulle novità accadute in Napoli l'anno 1647* (in the *Archivio storico italiano*, 1st series, vol. ix.).

MASARYK, THOMAS GARRIGUE (1850–1937), first president of Czechoslovakia, was born on March 7, 1850, in the Moravian border-town Hodonin. His father was a coachman employed on one of the Austrian Imperial estates, a native of Kop-

čany in Slovakia (Slovakia then being a part of Hungary); his mother came from a semi-Germanized Czech family of Hustopeč, in the Moravian plains. In his boyhood Masaryk was taught Czech and a smattering of German, and was educated at a Czech school in Čejkovice. His parents sent him for two years to the lower German Realschule of Hustopeč, with the intention of making him a teacher.

The object being abandoned, he became first a locksmith's apprentice in Vienna, then a blacksmith at Čejč. In 1865 his former schoolmaster induced his parents to resume their first idea of making him a teacher, and in that year Masaryk passed the entrance examination to the second grade of the "gymnasium," and began studying at Brno. He supported himself, as did many poor students, by tutoring. He developed a rebellious disposition, disagreed with some of the dogmas of the Roman Catholic Church and refused to go to confession. As a result he had to leave the gymnasium, and he continued his studies in Vienna, where he graduated first from the gymnasium with honours, then from the university, where in 1879 he became a lecturer in philosophy. He spent a year in Leipzig, where he met his future wife, Charlotte Garrigue, daughter of the president of the Germania Insurance Company of New York. In 1881 he published in German his first great sociological work, *Suicide as a Phenomenon of Modern Civilisation.* In 1882, when the University of Prague was divided into two parts, the one Czech, the other German, he was appointed to one of the Czech professorships. In 1885 he published his larger work on *Concrete Logic.*

The Forged Mss. and "Realism."—In 1883 Masaryk founded a critical monthly review *The Athenaeum,* which soon sprang into prominence by becoming the battle ground on which the famous mss. of Krlóové Hradec and Zelená (Koeniginhof and Gruenberg) were attacked and proved to be forgeries, manufactured in the early 19th century by two well-meaning men, whose object was to provide texts to prove that in the Middle Ages there had been a high standard of literary culture in Bohemia. The authenticity of the mss. had before been doubted by Slav philologists, but it was not until 1886, when Masaryk invited the great Czech philologist Gebauer to analyse the mss. philologically, himself analysing them sociologically, that they were conclusively proved to be forgeries.

The fight over the mss. was the real beginning of the so-called "realist" revolution in Czech politics, literature and philosophy, the guiding principle of which was the application of the scientific method to letters and politics. While at Prague university, Masaryk founded in 1893 a monthly review *Naše Doba* (Our Epoch). He became a member and instructor of the "Sokols." He started lecturing in Prague clubs and societies on unconventional subjects and published unpopular books. His sociological work led him to a study of Marxism, whose historical materialism he criticised in *The Social Question* (1898, in Czech and in German).

Masaryk's political career started in the early 'eighties. In 1887 his friends founded a fortnightly paper *Cas* ("Time"), which two years later he took over and transformed into a political weekly. At that time the so-called Old Czech (Conservative) party was losing ground, and Masaryk, invited by the Young Czech (Liberal) party to be a candidate, was elected to parliament in 1891. He soon resigned his seat (1893) to devote himself to a crusade of moral education among the Czech people.

Although his opinions on nationalist questions were unpopular —an unpopularity which increased when in 1899 he fearlessly withstood a popular anti-Semitic superstition as manifested in the so-called "ritual murder trial" of a Jew named Hilsner—his ideas made a deep impression. They became the rallying cry of the younger generation not only of the Czechs, but of the Yugoslavs and other Slavs who flocked to Prague.

Political Leadership.—In 1900 his followers founded a political party which was officially named the "Progressive party," but which continued popularly to be known as the Realist party. The programme was founded on the principles enunciated in Masaryk's books. As a candidate of the Realist party he was re-elected to parliament in 1907. In parliament he soon began to criticize Austria's passive subjection to Germany and her own aggressive policy in the Balkans, especially as manifested in the annexation of Bosnia-Hercegovina. In the notorious "high treason" trial of Agram (1909), by which the Austrian foreign minister, Count Aehrenthal, tried to justify his annexation policy, and in the Friedjung trial (1909) which followed, Masaryk played a decisive part. He proved, on the basis of his private investigations, that the case for the Crown rested on documents forged at the Austro-Hungarian Legation in Belgrade. His fearless disclosures in the Austrian Reichsrat (May 1909) and in the Austro-Hungarian delegations (1910) forced the proceedings in the Agram trial to be quashed, compelled Friedjung to retract his accusations against the Serbs, and unmasked the methods of Austro-Hungarian diplomacy. Masaryk incurred the intense displeasure of the official and court circles in Vienna, but made a reputation abroad.

Propaganda.—During the World War he developed his case against Austria-Hungary in detail, and at the end, in his work, *The New Europe,* characterized it as a corrupt, imperialist, militarist, pretentious and senseless relic of the middle ages. When the war broke out he was still a member of the Austrian parliament. In Dec. 1914 he escaped from Austria, and in the following four years conducted a political and propagandist campaign in Switzerland, France, England, Italy, Russia and the United States on behalf of Czechoslovak liberation from Habsburg rule. He founded the propagandist journals *La Nation Tchèque,* which was edited in Paris by Ernest Denis, and *Ceskoslovenska Samostatnost* (Czechoslovak Independence), which was produced in the small town of Annemasse in Savoy, and he was one of the original board of Dr. R. W. Seton-Watson's *The New Europe,* which was founded in London in 1916.

Masaryk's stand against Austria was publicly proclaimed in his Hus anniversary speech made in Geneva in July 1915, and reaffirmed in his revolutionary manifesto, issued by him with the sanction of the Czech political leaders at home, on Nov. 14, 1915. The signatories of that manifesto, who included representatives of Czech residents in France, Great Britain, America and Russia, formed a central revolutionary committee called the Czechoslovak National Council, of which Masaryk acted as president and Benes as secretary. Finding his work in Switzerland hampered by enemy spies, he settled in London, where, at the invitation of Ronald Burrows, principal of King's college, he joined the staff of that college. Here he worked for two years combating, with the help of his friends, Wickham Steed and R. W. Seton-Watson, the German-Magyar propaganda, and familiarizing Western opinion with Czechoslovak aspirations.

The Russian revolution of 1917 enabled him to go to Russia. Several thousand Czech soldiers—prisoners of war—had gone over to the Russians, and wanted to organize themselves into active military units. After some difficulty Masaryk induced the revolutionary Russian Government to agree to the formation and equipment of an independent Czechoslovak army (92,000), whose exploits as they marched eastwards from Siberia to Vladivostok were one of the impressive later episodes of the war. He transferred some of them to the western front.

President.—He went to the United States in May 1918. The result was the Lansing declaration (May 29, 1918) of sympathy with the cause of Czechoslovak and Yugoslav independence. The Allied Governments associated themselves with that declaration on June 3, 1918. The ice being thus broken, the Allied Powers and America recognized Masaryk's national council as the *de facto* Government of the future Czechoslovak State. Masaryk was elected first president of the Czechoslovak republic on Nov. 14, 1918, and re-elected on May 27, 1920. He had been sentenced to death *in contumaciam,* and in 1923 occurred the death of his wife, largely the result of persecution to which the Government had subjected his family. He was re-elected president in May 1927, and again in May 1934 but in Dec. 1935 he resigned. For his work from 1918 onwards *see* CZECHOSLOVAKIA.

Masaryk ranks equally high as a philosopher and as a statesman. His philosophical treatises were the result of his study of Czech history. His pronounced realism was a reaction both against the Teutonic idealism which developed moral speculation with-

out reference to the practical affairs of life and against the Tolstoyan Slav philosophy of non-resistance to evil Masaryk, as philosopher, stood for a unified conception of life, in which the spiritual and religious took their place with the intellectual and the political as aspects of an integral whole. The following are the chief of his many philosophical, sociological and political works.—*O Hypnotismu,* On Hypnotism (1880); *Sebevražda,* Suicide and Modern Civilization (1881, also in German); *Theorie Pravděpodobnosti a Humeova Skepse,* the Theory of Probability and Hume's Scepticism (1882, Ger. trans. 1884); *Blaise Pascal* (1883); *Theorie dězin dle zásad T. H. Buckle,* the Theory of History according to T. H. Buckle (1884); *Zakladové Konkretin Logiky,* Essay on Concrete Logic (1885, Ger trans. 1886); *Slavjunofilism I. S. Kirejevskeho* (1889); *Česká Otázka,* the Czech Question (1895); *Karel Havlíček* (1896); *Otázka sociální, filosofické a sociální základy marxismu,* The Philosophical and Sociological Foundation of Marxism (1898, also in German); *Jan Hus* (1899); *Rusko a Evropa* (1913, Eng. trans., *The Spirit of Russia,* 1919, etc); *The Problem of the Small Nations in the European Crisis* (1916); *The New Europe* (1918, French trans. 1918, Czech 1919, German 1922); *Světová Revoluce* (1925; German trans., 1927; Eng. trans, *The Making of a State: Memories and Observations 1914–18,* 1927; French trans, 1930). (G. G.)

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MASAYA, an important interior town of Nicaragua, capital of the department of the same name. Pop. (1928) about 20,000. Masaya is on the main line of the Pacific railway, 13 m. west of Granada, and 106 m. from Corinto. Lake Masaya, a crater lake on whose shore has risen the intermittently active volcano of the same name, adjoins the town, and round about it is a fertile region producing tobacco, beans, rice, maize, sugar and in the hills, coffee. A branch line of the railway, 27 m. long, connects at Masaya, the terminus being "Los .Pueblos," an important coffee section. Masaya has a large Indian population.

MASCAGNI, PIETRO (1863–), Italian operatic composer, was born at Leghorn, the son of a baker, and educated for the law; but he neglected his legal studies for music, taking secret lessons at the Instituto Luigi Cherubini. There a symphony by him was performed in 1879, and a kindly uncle helped him to study at the Milan Conservatoire. But Mascagni chafed at the discipline, and went off with a touring operatic company. After much hardship he suddenly leapt into fame by the production at Rome in 1890 of his one-act opera *Cavalleria Rusticana,* to a libretto based on a peasant story by Giovanni Verga (*q.v.*) containing a tuneful "intermezzo," which became widely popular. *Cavalleria Rusticana* was performed everywhere.

MASCARA, chief town of an arrondissement in the department of Oran, Algeria, 60 m. S.E. of Oran. It lies 1,800 ft. above the sea, on the southern slope of the mountains of Beni-Chougran, and occupies two small hills separated by the Wad Tudman. Mascara is a town of the French colonial type, few vestiges of the Moorish period remaining. Among the public buildings are two mosques, in one of which Abd-el-Kader preached the *jihad.* The principal industry is the making of wine, the white wines of Mascara being held in high repute. There is also a considerable trade in grains and oil. A branch railway eight miles long connects Mascara with the line from the seaport of Arzew to Ain Sefra. Access is also gained by this line to Oran, Algiers, etc. The population (1931) is 27,591 of whom 12,730 are Europeans.

Mascara (*i.e.,* "mother of soldiers") was the capital of a Turkish beylik during the Spanish occupation of Oran from the 16th to the close of the 18th century; but for the most of that period it occupied a site about two miles distant from the present position. On the removal of the bey to Oran its importance rapidly declined; and it was an insignificant place when in 1832 Abd-el-Kader, who was born in the neighbourhood, chose it as the seat of his power. It was laid in ruins by the French under Marshal Clausel and the duke of Orleans in 1835, the amir retreating south. Being reoccupied by Abd-el-Kader in 1838, Mascara was again captured in 1841 by Marshal Bugeaud.

MASCARENE ISLANDS (occasionally Mascarenhas), the collective title, derived from their discoverer, a Portuguese navigator Mascarenhas, of a group in the Indian ocean east of Madagascar, viz., Mauritius, Réunion and Rodriguez (*q v*).

MASCARON, JULES (1634–1703), French preacher, was the son of a barrister at Aix Born at Marseilles in 1634, he early entered the French Oratory, and obtained a great reputation as a preacher. Paris confirmed the judgment of the provinces, in 1666 he was asked to preach before the court, and became a great favourite with Louis XIV., who said that his eloquence was one of the few things that never grew old In 1671 he was appointed bishop of Tulle; and in 1679 bishop of Agen He still continued, however, to preach regularly at court, being especially in request for funeral orations A panegyric on Turenne delivered in 1675, is considered his masterpiece.

Six of his most famous sermons were edited, with a biographical sketch of their author, by the Oratorian Borde in 1704

MASCART, ÉLEUTHÈRE ÉLIE NICOLAS (1837–1908), French physicist, was born on Feb 20, 1837, near Valenciennes. He was educated at Paris and held the post of professor of physics in the lycées of Metz Paris and Versailles In 1872 he succeeded Regnault as professor of physics at the Collège de France, he also became director of the Central Bureau of Meteorology in 1878. Mascart retired in 1907 and died at Paris on Aug 26, 1908.

His early investigations were on optics; he constructed a quartz spectrograph and applied photography to the mapping of spectra Mascart investigated a number of spectra further into the ultra violet. He also made determinations of standard wave lengths His memoir on the effect of the proper motion of the earth on optical phenomena was awarded the Grand Prix des Sciences Mathématiques in 1874. Mascart made a number of determinations of electrical units and determined the electro chemical equivalent of silver. Mascart was interested in the teaching of practical electricity and in its application to industry; he acted as adviser to the Government in many matters He was created a Grand Officer of the Legion of Honour, a foreign member of the Royal Society, and was awarded many honours He wrote *Éléments de mécanique* (1866), *Traité d'électricité statique* (1876), *Traité d'optique* (vols. i.–iv., 1889–93), *Leçons sur l'électricité et le magnétisme* (with Joubert, 1880), *Traité de magnétisme terrestre* (1900).

See obituary notice by Janet in *Revue générale de Sciences*, xx (1909).

MASCHERONI, LORENZO (1750–1800), Italian geometer, was professor of mathematics at the University of Pavia He published a variety of mathematical works, the best known of which is his *Geometria del compasso* (Pavia, 1797), a collection of geometrical constructions in which he uses the compass only, many of the solutions being most ingenious

There is a French translation by A. M. Carette (1798), who also wrote a biography of Mascheroni. *See* Poggendorff, *Biog. Lit Handwörterbuch.*

MASCOT, the term for any person, animal or thing supposed to bring luck (Fr. slang: perhaps from Port *mascotto,* "witchcraft"). The word was first popularized by Edmond Audran through his comic opera *La Mascotte* (1880), but it had been common in France long before among gamblers It has been traced back to a dialectic use in Provence and Gascony, where it meant something which brought luck to a household

MASDEU, JUAN FRANCISCO DE (1744–1817), Spanish historian and Jesuit. His *Historia critica de España y de la cultura española* (1783–1805) is written in a critical spirit and with a regard for accuracy rare in his time, but its author is more concerned with small details than with the philosophy of history

MASEFIELD, JOHN, O.M. (1878–) British poet and novelist, was born in Ledbury and spent his youth in many countries and occupations, serving before the mast at sea and earning a living as best he could in America. The activity of these years

MODERN MASKS

BY WLADYSLAW T. BENDA

At the top is a naturalistic mask with headdress attached. That at the centre and that to the right are realistic, though representing different types of humanity. The death's-head mask is typical of the grotesque sort, the treatment of the eye, in which a small glass globe is suspended on wire so as to allow it movement when the head is turned from side to side, being of special interest. In the lower mask, which is a caricature, the face is made smaller than that of the wearer, necessitating the introduction of eye-holes above the actual eyes. *See* text-cut figure two

was reflected in his work from the first, as *Salt-Water Ballads* (1902) or *Ballads* (1903) show. His early novels, *Jim Davis* (1911), *Captain Margaret* (1908) and *Multitude and Solitude* (1909), were excellent tales of action and spirit, but he found his natural expression in narrative poetry and drama. *The Everlasting Mercy* made something of a sensation in 1911; it was followed quickly by *The Widow in the Bye Street* (1912); *Dauber* (1913); and *The Daffodil Fields* (1913), all narrative poems in a key of stern realism. Meantime Masefield had written two plays, *The Tragedy of Nan* (1909) and *Pompey the Great* (1910), the first allied in subject and setting to his long poems of village life, the second historical in theme. *Lollingdon Downs* (1917) included a noteworthy sonnet sequence, and *Reynard the Fox* (1919) proved one of the most successful of his verse narratives. Here the country life that he knows so well is reflected faithfully and vividly, without the somewhat excessive gloom of *Nan* and the *Everlasting Mercy*. The gradual awakening of the village on the morning of the meet, followed by the gathering of the hunt, the stir and movement of horses and hounds, make a picture among the best things he has ever done. *Right Royal* (1920), a similar poem, is less successful. Later work includes *A King's Daughter*, a verse tragedy (1923); *Sard Harker*, a novel (1924); *The Trial of Jesus*, a play (1925); *Odtaa* (1926) and *The Hawbucks* (1929), novels. He published some able prose War sketches in *Gallipoli* (1916) and *The Old Front Line* (1917). He was made poet laureate in May, 1930, as successor of Robert Bridges.

MASERU, town, the capital of Basutoland and the headquarters of the Government, 29° 21′ S., 27° 31′ E., altitude 4,942 feet. Pop. (1921) 399 Europeans, 1,890 natives and 30 other coloured persons. It is situated near the Caledon River, most of the houses being built of the local, cream coloured sandstone. It is connected by railway with the South African system. There are several churches, an industrial school, a hospital and a number of stores. (*See* BASUTOLAND.)

MASHAM, ABIGAIL, LADY (d. 1734), favourite of Anne, queen of England, was the daughter of a London merchant, and cousin of Sarah Jennings, duchess of Marlborough, who procured her an appointment in the queen's household about 1704. The queen's presence at Abigail's private marriage to a gentleman of the royal household named Samuel Masham, first led the duchess to suspect that Abigail was supplanting her in the queen's favour. This suspicion was confirmed in 1710 when the queen compelled Marlborough to give an important command to Colonel John Hill, Abigail's brother; and when Sunderland, Godolphin, and the other Whig ministers were dismissed from office. In the following year the duchess was also dismissed from her appointment at court, and Abigail became keeper of the privy purse, shortly before her husband was created a peer. Finally, in July 1714, Anne, influenced by Lady Masham, dismissed Oxford from his office of lord high treasurer, and gave the staff to the duke of Shrewsbury. When the queen died on Aug. 1, Lady Masham retired into private life. She died on Dec. 6, 1734. (*See* ANNE, QUEEN; MARLBOROUGH.)

MASHAM, SAMUEL CUNLIFFE LISTER, 1ST BARON, cr. 1891 (1815–1906), English inventor, born at Calverley Hall, near Bradford, on Jan. 1, 1815, was the fourth son of Ellis Cunliffe (1774–1853), who successively took the names of Lister and Lister-Kay, and who was the first member of parliament elected for Bradford after the Reform Act of 1832. In 1838 Samuel and his elder brother John started as worsted spinners and manufacturers at Manningham, and he turned his attention to the problem of mechanical wool-combing. Two years of hard work spent in modifying and improving existing devices enabled him to produce a machine which worked well; and he consolidated his position by buying up rival patents, as well as by taking out additional ones of his own.

In 1855 he was sent a sample of silk waste (the refuse left in reeling silk from the cocoons) and asked whether he could find a way of utilizing the fibre it contained. The task occupied his time for many years and brought him to the verge of bankruptcy, but at last he succeeded in perfecting silk-combing appliances which enabled him to make yarn that in one year sold for 23s. a pound, though produced from raw material costing only 6d. or 1s. a pound. Another important and lucrative invention in connection with silk manufacture was his velvet loom for piled fabrics. In 1886 an Albert medal was awarded him for his inventions. He died at Swinton Park on Feb. 2, 1906.

MASHONA: *see* KARANGA.

MASKELYNE, NEVIL (1732–1811), English astronomer royal, was born in London, on Oct. 6, 1732. He was educated at Westminster school and Trinity college, Cambridge, where he graduated as seventh wrangler in 1754. He was ordained in 1755, but his interest in astronomy had been aroused by the eclipse of July 25, 1748, and in 1761, on Bradley's recommendation, he was deputed by the Royal Society to observe the transit of Venus in St. Helena. During the voyage he experimented upon the determination of longitude by the method of "lunars," and introduced this method into navigation by publishing in 1763 the *British Mariner's Guide*. In 1765 he succeeded Bliss as astronomer royal. Maskelyne's chief aim was the practical improvement of the art of navigation and in 1766 he published the first volume of the *Nautical Almanac*. He continued the superintendence of this, his greatest work, until his death on Feb. 9, 1811.

Maskelyne's first contribution to astronomical literature was "A Proposal for Discovering the Annual Parallax of Sirius," published in 1760 (*Phil. Trans.*, li. 889). Subsequent volumes of the same series contained his observations of the transits of Venus (1761 and 1769), on the tides at St. Helena (1762), and on various astronomical phenomena at St. Helena (1764), and at Barbados (1764). In 1772 he suggested to the Royal Society the famous Schehallion experiment for the determination of the earth's density and carried out his plan in 1774 (*Phil. Trans.*, l. 495). From Maskelyne's observations Chas. Hutton deduced a density for the earth 4·5 times that of water (Ib. lxviii. 782).

See *The Royal Observatory, Greenwich* (1900), which gives an account of his life and work.

MASKS, coverings for the face, taking various forms, used either as a protective screen or as a disguise. In the latter sense masks are mostly associated with the artificial faces worn by actors in dramatic representations (*see* DRAMA) or assumed in savage rites for exciting terror.

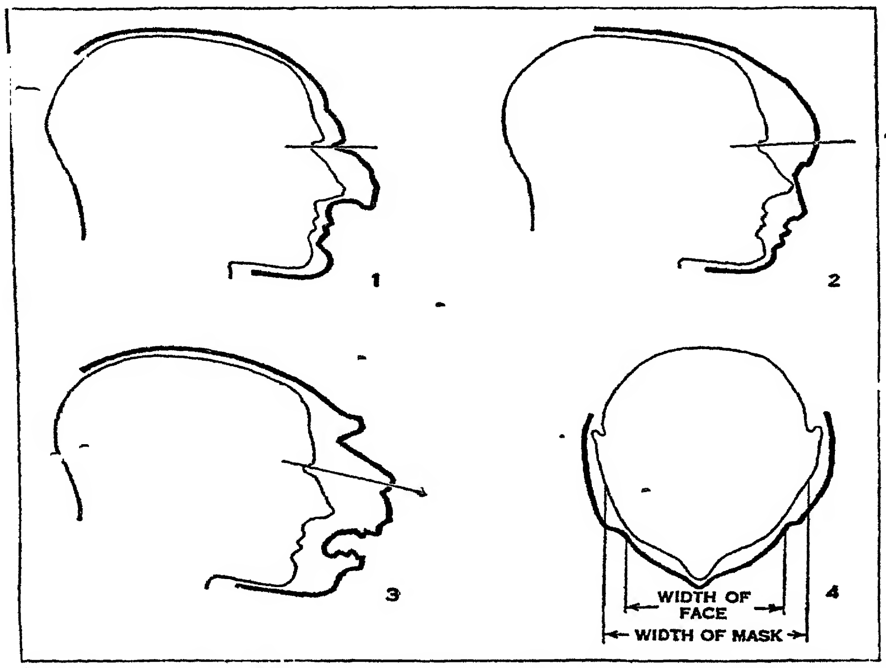
The mask was primarily a ceremonial and religious object, its secular and festival employment being secondary. Man made gods in his own image, but their early, if not their first, dwellings were the bodies of human creatures. Auto-suggestion and drugs were used to secure divine possession and the appearance of the destined individual was made inviting. Clothes, adornments and, above all, facial masks were used for this purpose, the latter bearing a special significance in that the countenance was regarded as the most definite symbol of divine intelligence. Masks were employed also to perpetuate the appearance of the living after death and placed upon the mummy, as among the Egyptians, to aid in its revivification.

Our own culture is not directly and deeply rooted in primitive conditions, nor was that of the Greeks and Romans from whom we derive the great mass of our literary and artistic traditions. We know the mask as they knew it—as an appliance of the theatre, and as a festal object. As such it exists in Tibet, China, Japan, Burma, Siam, Ceylon and Java, identified with dances and dramatic performances comparable to the miracle plays of mediaeval Europe.

Greece.—Among the Greeks the origin of the mask is looked for in the grotesque jocularities of the Dionysian worship. The drama adopted masks of painted canvas. Owing to the large size of the Greek theatre, acoustical and optical means had to be applied to convey the words and gestures of the actors to the more distant rows of spectators. One of the latter was the apparent increase of the actor's size by means of the cothurnus and high masks. The development of the mask into a covering, not only of the face but of the whole head, with side and front hair attached to it, was ascribed to Aeschylus. Openings were left for the mouth and eyes, the latter not being larger than the pupil of the eye and the former only just wide enough to afford egress to the voice. This was the case at least in tragedy. Comic masks, on the other hand, showed distorted features, and a mouth widely

opened, the lips serving as a kind of speaking trumpet. Several of the manuscripts of the plays of Terence contain illustrations of the masks used by actors. In all cases the mouth appears to be fashioned in the form of a large bivalve shell for the sake of resonance. They were attached to a sort of cap which covered the head.

Among the remains of the Greeks and Romans is a very large and constantly increasing series of artistic representations drawn



FIGS 1–4 —DIAGRAM SHOWING SOME OF THE POSSIBLE VARIATIONS OF SIZE IN THE FACES OF MASKS

1. Mask face slightly larger than that of wearer
2. Mask face considerably smaller than wearer's, vision aperture in hair
3. Mask face considerably larger than that of wearer
4. Horizontal section showing mask with narrower face than that of wearer

from the stage and exhibiting, especially in the comic and satyric line, every conceivable variety of character. In some cases these characters are the same as may be seen in our day, *e.g.*, the punchinello. It would not be fair to the ancients, particularly the Greeks, if we judged their notions of the effect of a mask by our standards. Apart from their employment in the drama, the foremost usage of masks about which there is some certainty is sepulchral. In the tombs opened by Schliemann at Mycenae he found gold masks over the faces of the dead. These could not have been portraits unless they were intended to represent the deceased persons as they looked when dead, for there is a death-like expression on them and on all other masks hitherto discovered on or beside the faces of the dead in Roman and Greek tombs. Murray suggests they were made with some resemblance to cover the face during the interval between death and interment when relatives and friends were admitted to see the body, or in the case of the Romans when the body was publicly conveyed to the market place previous to combustion. This conjecture is still more applicable in those cases where masks, always with a death-like expression, are attached to helmets in such a way as to cover the head entirely.

The terra-cotta masks occasionally discovered in Greek tombs, which vary in scale and hardly ever attain life size, appear to have been hung up against the walls in the interior of the tomb. Most of them represent a female face which has been taken as intended for Persephone, the goddess of the lower world, and in that case the mask may have been meant to propitiate her.

Japan.—Masks are said to have been introduced into Japan from China about the 7th or 8th century, probably in connection with Buddhism, and exist there in a greater variety of definite forms than in any other country in the world. The best known and largest number are used in the Nō, a form of drama which originated in Japan at the beginning of the 14th century and was inspired by Buddhist priests of the Zen sect and the pleasure-loving Shogun Yoshimasa (*see* NŌ DRAMA). One of the oldest masked dances, is the sambasso, said to have originated in a religious performance which took place at Nara in 807 to stop the progress of fissures which suddenly opened in the earth

Masked dances imported from China existed in the Japanese court from early times under the general name of Bu-gaku, or court dances. They were executed in the palace or temples, the performers were court nobles The music, imported from China, was highly complicated and the masks of very large size These dances, which were revived at the beginning of the 19th century, may be regarded as the progenitors of the Nō There are some 250 Nō plays, the same masks, of which there are over 100 named varieties, often being used in a number of different plays Human beings, men and women, gods, demons and animals are represented. The more ancient, dating from the 12th and 13th centuries have hard, strong features and remarkably large noses Only the principal performers are masked The actors are all professional and as there are no women among them the female parts are taken by men.

The material of the Nō masks is wood, with a coating of plaster which is lacquered and gilded The name is generally written inside, often in red. Many bear the name of the carver and fine old specimens are highly valued In addition to the No masks and others of a ritual character, there are a variety of masks used as toys by children, some of the latter, like the fox mask, emanating from shrines where they are sold at festivals A defensive mask of wrought iron was attached to the helmet This served not only as a defence, like the visor on the European helmet, but was made fierce in aspect in order to terrify the enemy Such use of masks, as for example the Gorgon or Medusa's head occurs in classical antiquity. Masks were used for this purpose in the decoration of shields, such as the Chinese basket-shield bearing the head of a red-faced monster with long, gleaming teeth, a device which has been traced from China to the Dyaks in Borneo

Tibet.—In Tibet were the sacred dramas illustrating the former births of Buddha, and similar events are performed by lay actors; a mystery play with manifestations of gods and demons by awe-inspiring masks is performed exclusively by the priests or Lamas at fixed seasons of the year This play appears to have been a devil-dancing cult for exorcising malignant demons which was given a Buddhistic dress and is still called the "Dance of the Red Tiger Devil," a deity of the Bon or pre-Buddhistic religions of Tibet. The masks used in this play in Tibet are made of papier mâché and cloth and occasionally of gilt copper In Sikhim and Bhotan, where wood is abundant and the damp climate destructive, they are carved of durable wood in all cases fantastically painted, and provided with a wig of yak-tail of different colours. Waddell classes them in five groups. (1) the king of the ogres, with a hideous mask of huge size with projecting tusks and three eyes; (2) the ten awful ogres and ten ogresses, with a variety of animal masks, bull, tiger, lion roc or garuda, monkey, stag and yak; (3) the ghouls with skull masks and clothes representing skeletons; (4) the earth-master-demons with large hideous masks but only one pair of eyes, as representing their subordinate position; (5) the teachers who represented the early Indian priests who brought Buddhism to Tibet, the buffoons or jesters of the play. They wear small cloth masks of ordinary size and of white clay or black colour. With them are included a personator of Hiuen Tsang, the famous Chinese Buddhist monk of the 8th century, who wears a huge silly-looking mask.

The sacred dramas, based upon the Jatakas or former births of Buddha, and performed by professional lay actors and actresses, are very popular. The buffoons who wear blue masks adorned with cowls are usually the so-called hunters, but sometimes, as in the old Hindu dramas, are Brahmins.

China.—Masks usually made of papier mâché are employed in the Chinese theatre, but for the greater part the actors make up their faces like masks with cosmetics and paint. These painted masks are of different colours, used singly or in combination, and have a traditional significance. For example, a corrupt ruler is given a white mask, a just man a red, and a violent and brutal

1 2 3 4 5

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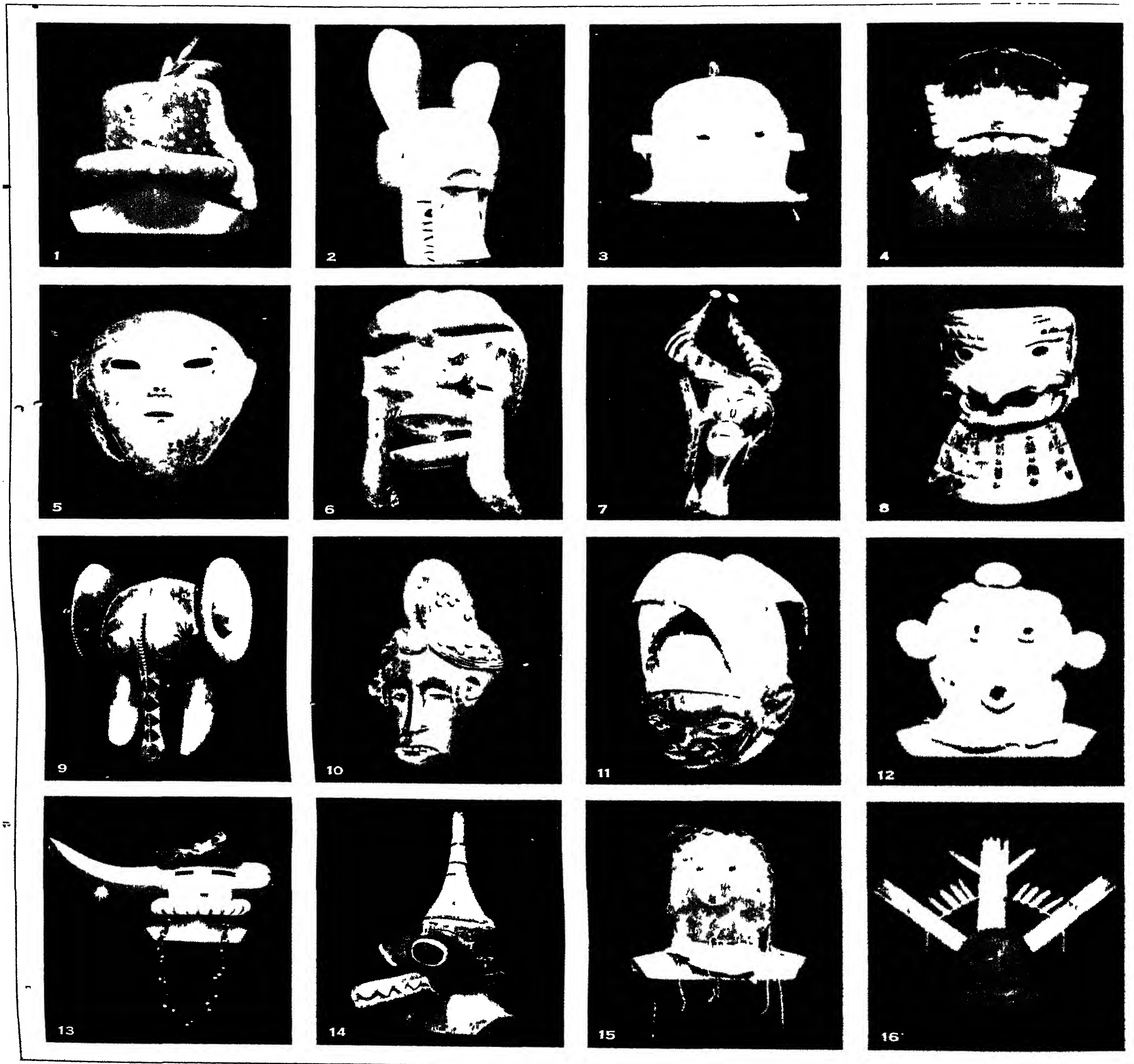
ANCIENT MASKS

1. Egyptian tragic masks made of faience (c. 100 A.D.). From Medinet-el-Fayum
2. Female tragic mask of terracotta; Greek, of the Hellenistic period. From Thebes
3. Colossal tragic mask of marble; Roman period
4. Ancient Tibetan Mask; probably used by a devil dancer
5. Bronze helmet found at Ribchester, Lancashire. In the Townley Collection, British Museum

MASKS



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ANCIENT MASKS

1. Fire God mask. Zuñi Indians New Mex 2. Ant bear mask. Belgian Congo. 3. Rainbow mask. Keres Indians, New Mex. 4 Yebichai mask. Navajo Indians, New Mex. 5. Congo mask of carved wood. 6. Gorilla mask. Belgian Congo. 7. Antelope mask. Belgian Congo. 8. Japanese war mask. 9. Elephant mask. Belgian Congo. 10. [illegible] mask Liberia 11. Mask from Nigeria. 12. Clown mask Zuñi Indians. 13. Long horn mask. Zuñi Indians. 14. Mask of [illegible] Hopi Indians, New Mex 15. Tobodzistsini, Navajo War God, mask. 16. Mask of the Apache Indian

man, a black mask. There are no special theatre buildings, but almost every temple has a stage erected in a convenient part devoted to the performance of theatrical representations. In addition to the secular and historical dramas, which are extremely popular, there are plays and other performances in which masks are used all more or less bound up with Buddhism. Masks are also used in various ways by children in traditional observances.

In Tibet, China, Japan and other adjacent countries to which Buddhism extended, the so-called lion dance is popular. In Tibet the head and shoulders of the lion are formed by a framework which one man manipulates from the interior while another man occupies its hind quarters. A harlequin mummer with a variety of rough and tumble antics introduces the beast, which enters with leaps and bounds and goes through a variety of manoeuvres. In China, where this sport is common, a ball in imitation of an immense pearl is carried by some one who runs in front of the beast or darts across its path. The lion is believed to be extremely fond of playing with the ball A similar amusement is practised in China and Japan by itinerant players who carry a red mask of a lion on a pole, their bodies being concealed by a dependent red cloth. The mask and cloth are manipulated violently as if the animal was in pursuit, to the taps of a small drum. The lower jaw of this mask is movable and is made to emit a loud continuous clacking by means of a string. The same mechanism is used in the goat mask found in the Tyrol and among the Slavs and again in the giant masks of the Zuni Indian, shalako.

Ceylon and Java.—In Ceylon masks are used in plays, masquerades and devil-dancing. Those representing various diseases are employed by dancers in exorcising the spirits who are believed to cause them. The masks used in these performances are of carved wood, painted in brilliant colours, yellow and red preponderating. Some, like that of the great demon of fatal diseases, all of which are attributed to the derangement of the three humours, wind, phlegm and bile, are composite and of enormous size. The demon of cattle, who causes cattle sickness, is represented with horns and tusks and is clothed in a garment of leaves. The Gara is a demon who possesses newly-built houses, and before a house can be fully occupied a ceremony is generally performed. The masks are not intended to drive the devils away but rather to attach them to the spot.

In Java wooden masks, *tupeng*, are used in certain of the theatrical performances that are extremely popular. These plays, developed from the shadow puppet plays of the 18th century, are performed not only as amusements but to safeguard the people from all kinds of calamities The stories are in part derived from ancient Sanskrit literature, the Mahabharata and the Ramayana, although the Javanese are now Mohammedans. This use of masks is exceptional, for masks, being forbidden under the prohibition of images, are practically unknown in the Mohammedan East.

Melanesia.—Masks of bark and carved wood play an important part among the Papuans where they are worn by members of the native secret societies. There societies such as the Quatu of New Hebrides, the Tamate of the Banks islands, the Malambala of Florida, the Dukduk of New Britain, etc., are characteristic of Melanesia and are accessible only to men.

Africa.—Carved wooden masks are used by the natives of the Congo and by the adjacent tribes on the west coast of Africa. They may be divided into three principal classes: war masks, dance masks and masks of the *féticheur*,—that curious personage who combines the attributes of high priest, magistrate and physician Whatever their use, they are more or less connected directly with the medicine man and are religious rather than festal. The face or head of carved wood is usually painted and supplemented by an enormous fringe of fibre attached at the base of the mask and hanging over the shoulders. In their expression the African carved wood masks have an artistic distinction above those of any living people.

Eastern Europe.—Masks survive among the Slav peasants of eastern Europe in connection with heathen festivals connected with the winter solstice that have been transferred to Christmas and Easter. The carved and painted wooden masks of the peasants of the Austrian Tyrol, among which those of the so-called Judas play are conspicuous, frequently bore branching stag horns, and are reminiscent of an earlier, heathen period, as are the masks used in the May dances by the peasants in other parts of Europe Little or no information exists concerning the use of masks in Europe after the decline of the classic drama until they reappear in the mediaeval mystery plays, and their use evolved through the mimes and Italian popular comedy into pantomime. The masquerade came from Italy where the domino, a loose cloak with a half mask, was introduced from Venice.

America.—Whatever may be the status of the mask in the culture of the Old World, it is surpassed in America where it was a fundamental object in the religious life of many aboriginal tribes. As such it culminated in the ancient civilization of Mexico where it not only distinguished the personalities of the gods but supplied the foundation of the system of picture writing in which the individual characters consist for the most part of grotesque masks of different divinities. While all but a very few of the old masks have perished, they may be studied in the minutest detail from the pictures in the manuscripts and from sculpture and pottery. Sculptured stone masks with holes at the upper corners for attachment or suspension are common among Mexican antiquities, and while their use is not fully understood, actual masks of carved wood entirely encrusted with turquoise are preserved in museum collections.

The primitive culture of the Americas appears to belong to an earlier and fresher stratum than that of the oldest historic civilizations; it exhibits processes of growth and development that are elsewhere lacking. This is especially true of the mask, for which we find a direct explanation which, while it may not apply to all masks, reveals materials and conditions out of which the thing came into being.

While the use of the mask among the American Indians was widespread, the Eskimo, the tribes of the north-west Pacific coast and the village dwellers of the south-western United States are now our chief sources of information Idols or images of the gods are inconspicuous in the religious life of the existing Indian who himself personates his deities. He identifies himself with the divinity by painting himself, or by his costume, the essential feature of which among the Indians of the South-west is the mask. Much the same kilts, girdles and other accessories are worn with different masks. The Eskimos believe that in early days all animated beings had a dual existence, assuming at will either human or animal form. When an animal wished to become human it raised its forearm or wing and pushed up its muzzle or beak as if it were a mask, the creature becoming instantly manlike in form and features. The manlike form thus appearing is supposed to represent the thinking part of the creature and at death becomes its shade. The masks of the Pacific coast with double faces illustrate this belief, the muzzle or beak of the animal fitting over and concealing the face of a man and being so constructed as to swing open and symbolize the transformation at a certain place in the ceremony.

The primal and dominant type of mask employed by the Indians of the south-western United States is a cylinder, closed at the top, that fits over the head and rests on the shoulders. It suggests and is comparable to the top of a carved post. Another mask, a section of the foregoing, covers only the face. These are worn alike by the Zuni, the Hopi, the Keres, Tewa and other Pueblo tribes. To-day they are made of leather, of old saddles, or of raw hide, and are humanized and adorned by a variety of adjuncts. The eyes are represented by round or square incisions or by two buckskin balls filled with deer hair and tied with deer sinew which passes through holes. The nose is commonly of buckskin rolled up and tied in place with sinew, or of a corn-cob or a corn-cob dart or a miniature dart directed at a ring which forms the mouth. The mouth is a little hole with a ring of buckskin or is indicated by a braided corn husk simulating teeth. Not infrequently it has a projecting wooden cylinder for a bill, or the stem of a gourd cut with teeth for a snout. Ears consist of a hemispheric disc of wood perforated for earrings and attached with sinew or buckskin strings, or flowers of the

colour-vision producing datura made of wool or cotton yarn of different colours, or datura flower buds of wood, on one or both sides. On others painted discs representing datura flowers with segments of different colours are substituted. Horns are attached to some masks. Others are surmounted by wooden rainbows or rectangular tablets. A feather plume is frequently affixed at the top. Wooden arrows, lightning sticks and cloud terraces are among the other adjuncts.

These masks are painted in colours: blue, green, white, black, pink, red, yellow, brown, purple and grey, and are adorned with plumes and beads. All have sex, masculine or feminine, which is not determined by the beard. In graphic representations the round heads are masculine and the square, feminine. The masks are collected by a head man at his house before each dance and decorated for the occasion. After the dances they are dismantled and taken, each to its owner's home where they are kept in a back room tied in a cloth. The same mask may be used in different dances, painted and adorned in accordance with their requirements. Masks are regarded as sacred and the spirit of the divinity they represent is thought to reside in them. Altars formed of them set in a row are sprinkled with sacred meal. Men invoked their masks, thanking them for services rendered. The wearer of the mask believes he is transformed into the mythic creature it represents. When he removes it he feels obliged to wash and purify himself. Among the Hopi a ceremony is performed to make this removal effective, through fear that the spirit may remain and disturb its possessor.

Masks and masked dances were articles of traffic between individuals and different Indian tribes. The Yeibichai dance of the Navajo is closely inter-related to the shalako dance of the Zuni Indians in which tall giants appear. In the shalako, the personators carry the masks upon poles, their heads and bodies being covered with a huge crinoline, painted to simulate feathers, through which holes are cut for their eyes. The masks used by the Navajo in the Yeibichai, as the night chant is called, are copies of the cylinder and face masks of the Pueblos, but are made of soft buckskin, great care being taken in their manufacture which is attended with elaborate ceremonies. Among the Pueblo Indians who have remained more or less under Christian influences, their old masked ceremonies are celebrated in a much modified form on the days of Christian church festivals and such is the custom generally among the Indian tribes in Mexico, who for the most part are Catholics.

No traces of masks are found among the remains in the Cliff Dwellings and it may be presumed that their existence among the Pueblos dates from a comparatively recent time and that they were introduced from old Mexico, their original source, at or about the time of the conquest. The gods they represent were originally bird-tree-gods, and the masks sections of trees. Made now of leather they were originally of hollow wood. Bird-tree-gods, personifications of the Four Directions, play a dominant part in the mythology of the native people of Mexico and Central America.

Among the tribes of the north-west coast two kinds of masks are distinguished: dancing masks and masks attached to house-fronts and heraldic columns. All masks of the latter kind are clan masks, usually three to five feet high, and have reference to the crest of the house or post owner. The dancing masks are those used at the Potlatch, the festival at which property is given away, and the masks of the mimical performances in winter when dances representing the traditions of the clan are acted. Some have human and others animal faces, bear, wolf, dog, beaver, crane, puffin and killer whale, represented in their mythology. They are commonly made of cedar wood, many are elaborately carved.

Carved wooden masks survive in use among Iroquois Indians in New York State and in Ontario, Canada, and archaeological remains indicate their use among the Indians of the eastern United States. Being perishable, the older masks of the aboriginal inhabitants of America have for the most part disappeared, but a suggestion that they may have existed widely is found in the carved and painted wooden masks discovered by Cushing at Marco, Florida.

Masks are less common among the South American Indians than in North America, although archaeological remains indicate that they had an important part in the old culture of Ecuador and Peru. Masks are used by the tribes of Guiana and on the Amazon, and in Tierra del Fuego bark and seal hide dance masks representing fish, suggesting the New Mexican Pueblo Indian masks, are used by the Yaghan. Actual masks are extremely rare among Peruvian remains, although terra cotta masks have been found in graves and Gigilioli reports two masks made from the facial portion of human skulls as having been discovered in an ancient cemetery near Lima. These objects, which appear to be true masks and used as such, are analogous to the skull masks of New Britain, the only other locality outside of ancient Mexico in which such masks are known to be employed.

It was the custom of certain of the old Peruvians like the ancient Egyptians to place above or before the envelopes of their dead, destined to a natural and not an artificial mummification, a rough image of the deceased when living. This was a wooden face, fixed with a peg on the upper part of the envelope in which the corpse was bound up, usually painted and adorned with a wig of human hair and a more or less complicated head-dress. (*See* THEATRE; DANCE; PANTOMIME; DRAMA.)

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MODERN MASKS AND THEIR USES

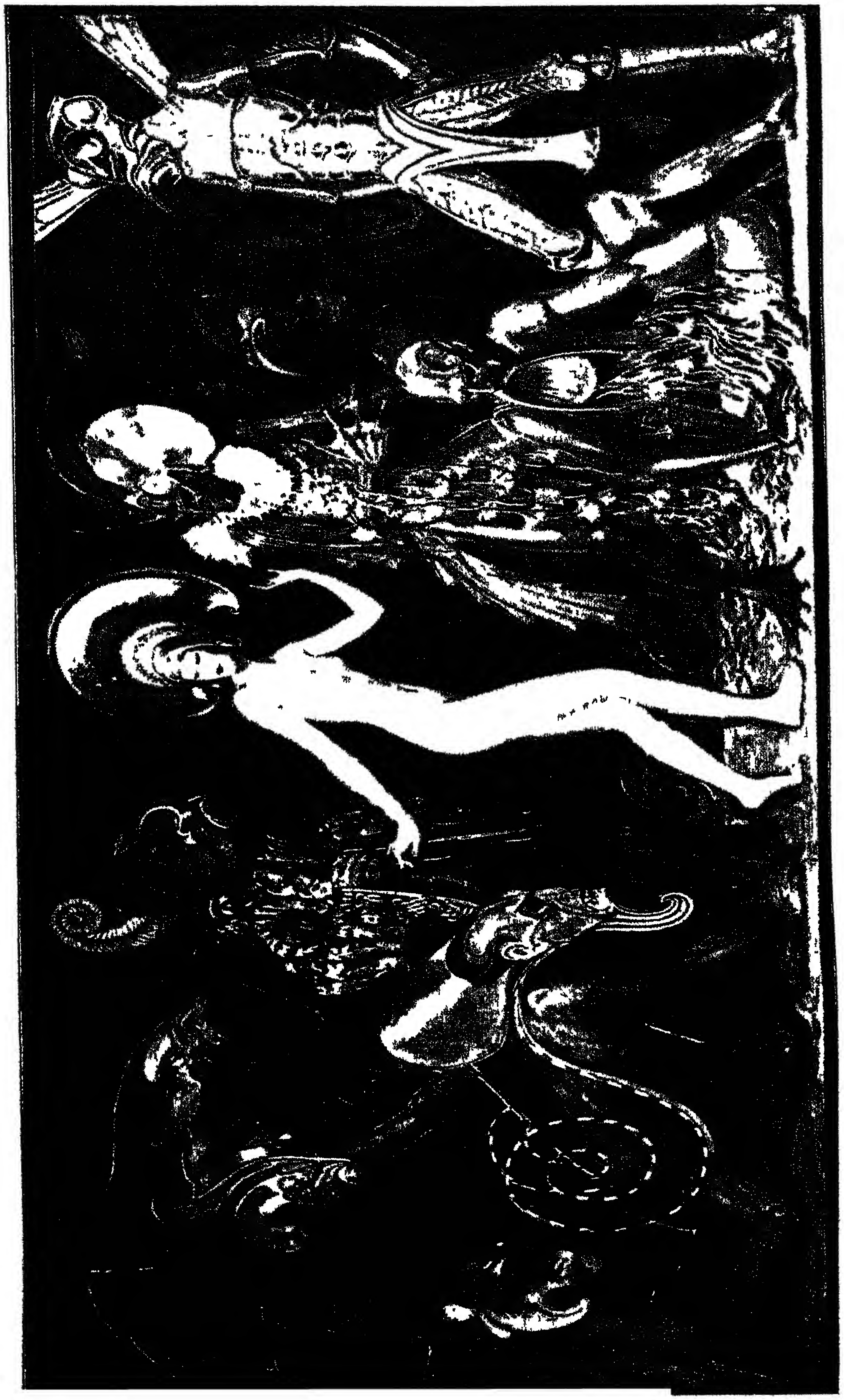
Our civilized world has neglected and forgotten the use of masks and it is only in this century that the interest in them has revived. We are here concerned solely with modern masks as the products of artists' imagination, taste and skill—masks that have quality which makes them different from and superior to all trivial products of manufacture and all banalities of the sort popularly called "false faces."

Early Significance.—Although the ritual and religious significance that prevailed in antiquity and exists now among primitive and barbaric people is unknown to us, there remains the mystery that envelops the mask, the same mystery that is at the bottom of all the supernatural meanings with which the ancients and the modern primitive people surrounded the masks and gave them such prominent part in their religious ceremonies; for when a person, no matter how sophisticated or naive, confronts a masked man, that person will be mystified. The mask may or may not fascinate, it may or may not terrify, it may appeal to the sense of humour or fail to do so, but it will never fail to mystify.

Psychological Effects.—This strange mystifying quality of the mask, the way it deceives and impresses us, the way we react to its inscrutable charm, when we see it worn by someone, and the way the wearer of a mask is influenced by the mask he is wearing, constitute a strange psychological phenomenon. The moment a person puts on a mask he changes into another being; his whole body seems to change its appearance, its proportion and character, and the onlooker immediately forgets his real features, even if the masked person is an old friend.

As various masks are put on the same person his figure will seem to alter. Its proportions and character become in the eyes of the spectator the figure belonging to the mask, and this is most convincing when the figure is nude. An ugly face makes the whole figure appear ungainly, just as a beautiful physiognomy will bring to our consciousness its beauty and grace.

There are of course certain obvious and simple facts which every art student knows and which are dominant in this deception. One of them is the proportion of the size of the head to the height of the body: a large face dwarfs the figure and a



MODERN DRAMATIC MASKS

MURAL PAINTING BY WLADYSLAW T. BENDA SHOWING THE DRAMATIC USE OF MASKS AS THEY ARE EMPLOYED IN GROTESQUE PANTOMIME

small head makes the figure appear taller. More exactly, if the length of the head is less than one-eighth of the whole figure the figure will appear very tall. This can be done, because, paradoxical as it may seem, it is possible to fit a mask with a smaller face over a larger face as the diagram shows in fig. 3

A mask in action seems to change its expression. This is a strange delusion which can be explained in the first place by the

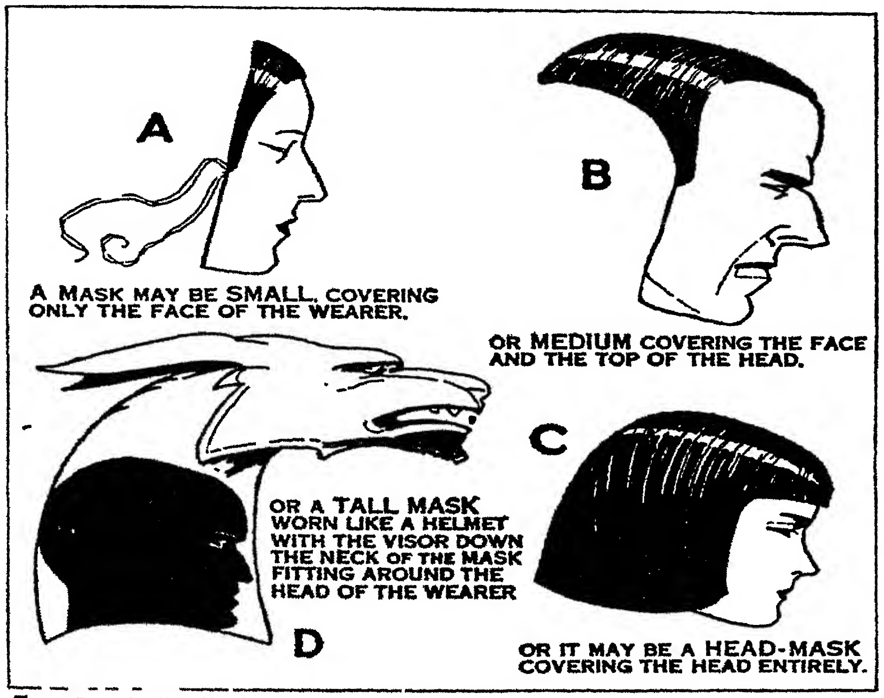


FIG. 5.—VARIOUS TYPES OF MASKS COVERING THE WHOLE OR PART OF THE HEAD

fact that the so-called facial expressions are not due to the contraction of the facial muscles, but are brought about by the movement and position of the head and the neck in relation to the rest of the body. This may be seen in Plate V., fig. 1, 2, 3 and 7, 8 and 9. Thus when the masked actor changes the position of his head we are under the impression that something has changed in the expression of the mask. A frowning man when his head is up looks aggressive, proud, pugnacious and commanding, but that same frown will give him an expression of sorrow and suffering if the head is lowered.

All this constitutes the effect that masks have on the onlooker. The wearer of masks is subject to another strange influence: as soon as he puts on a mask and starts to interpret its character through the action of his body, he will find his face unconsciously imitating the expression of the mask and he will find it difficult to stop this wasted mimicry. It would be amusing to see the rugged or stern masculine face of the wearer endeavouring to conform itself to the delicate and alluring femininity of the mask that covers it; or twisting itself into the snarling fierceness of an ape, if that happens to be the mask he is wearing. But it is natural that the face must co-ordinate itself with the action of the body, and, moreover, the expression of the mask is reflected in the faces of the spectators and back to the wearer. For instance, a man wearing the mask, with the supercilious expression shown in Plate V. would find that people looking at him were all grinning in response and he in his turn would grin at them even though his face was hidden.

DESIGN AND CONSTRUCTION

The creator of masks finds a great thrill and constant stimulus in the wide scope before him; in the limitless variety of types and expressions; in the degree of realism or fantastic exaggeration; in all shades of tragedy, comedy and burlesque. All the long gamut from noble countenances and alluring feminine beauty to terrifying demons, hobgoblins and all sorts of fantastic beings of utmost grotesqueness, besides the infinite possibilities of colour, are at his disposal. This variety may be divided into three distinct categories: (1) Masks representing in a more or less realistic manner types of men and women. (2) Grotesque masks, demons, gargoyles and fantastic representations of animal characteristics (*see* Plate III.). (3) Caricature.

The masks of the first category may portray single individuals or generalized types, and these last based on synthetic studies of human characteristics are the most interesting problems for the creator. There is therefore no excuse for indulging in meaningless creations, thoughtless imitations or other such banalities that would bring the standard of the modern mask back to the trivialities of recent products of manufacture that degrade it. Each mask should be the result of a thrilling inspiration and long and careful meditation based on accumulated knowledge. It must be impressive and full of significance; it must be more impressive and interesting than a human face,—all of which means that it must be a work of art. A modern maker of masks should get well acquainted with the wonderful masks of the ancients, and those of the barbaric peoples and primitive tribes, not to imitate them but to try to emulate their excellent qualities, their vigour and significance.

Imagination and the ability to model and paint could not go far in creating masks without the support of the knowledge of anatomy, zoology and anthropology, an understanding of racial differences, of the psychology of the human physiognomy, and of humanity as a whole. The mask must be convincing to be effective; therefore it must be based on the study of nature. This

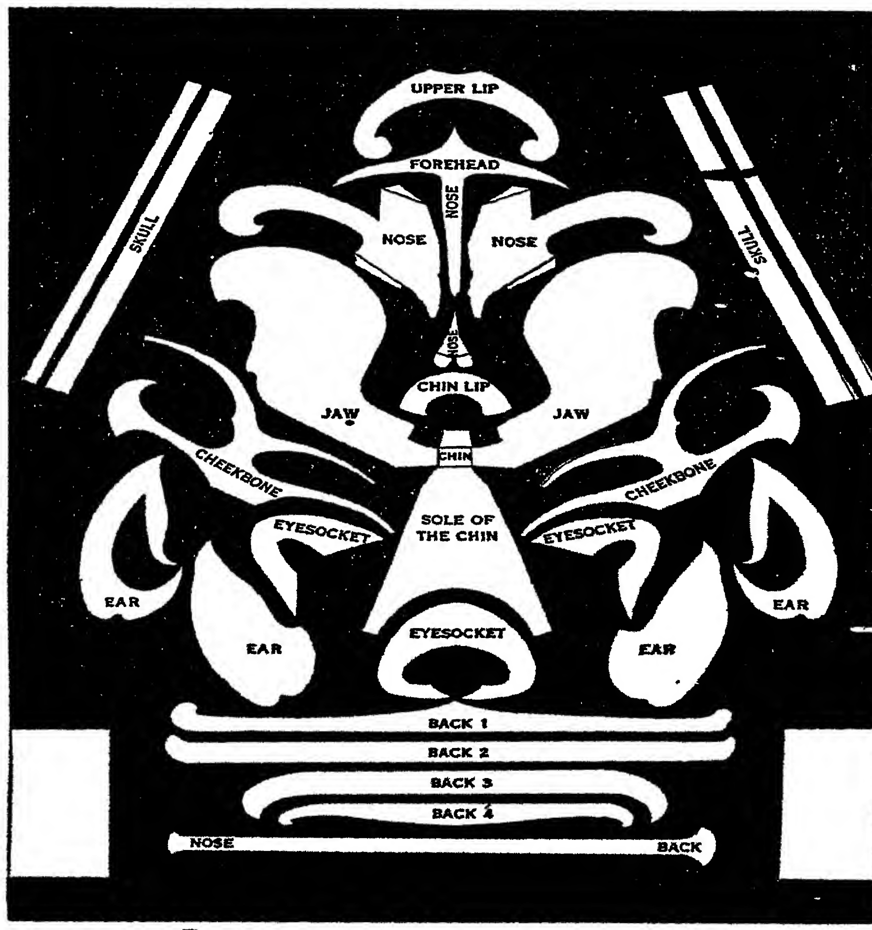


FIG. 6.—SECTIONS OF A GROTESQUE MASK

does not mean that it should always be naturalistic and realistic but even the most fantastic exaggerations in the grotesque masks should be based on that knowledge. Their structure, no matter how bizarre, should be evolved from real forms that exist in nature, human or animal. We must feel the bone construction of the face, the tenseness or relaxation of the facial muscles and the quality of the skin. And all this does not mean that there is

need of infinitesimal details. On the contrary, the effectiveness of a mask depends largely on the mystification by elimination of unimportant details and on the emphatic statement of everything that is essential in the type and expression.

Materials.—A mask to be practical should be: (1) durable—it should not break, crack, tear, warp, melt or stretch; (2) waterproof; (3) light in weight; (4) adjustable. Furthermore, it should have openings for the eyes and for breathing, and, in all cases, a surface that can be cleaned and washed.

To make a mask strong a durable material must be chosen, and then the mask so constructed that the durability can be ensured. This durable material should have other qualities that allow freedom of execution. Metals, wood, paper, rubber, silk, linen and papier mâché are possible materials

Papier mâché is the poorest material for such masks. It is weak and perishable and does not yield itself to refined finish. It is impossible to work into it delicate details or sharp edges. Wood is the material that has been used in all parts of the world. Japanese, American Indians, African tribes and South Sea Islanders carved masks out of wood. Although some of the most beautiful masks have been made of this material, it has a drawback in that the mask must be thick to prevent splitting, and consequently is not easily adjustable. That happens often—the beautiful Japanese Nō masks often split. Wood, however, remains one of the best mediums. Tough paper tightly glued in layers and covered outside and inside with waterproof varnish and oilpaint is better and stronger than wood; it cannot split, and the masks made of it can be thin and adjustable.

Modelling.—It is hardly possible to make a life-size mask that would fit well any size and shape of head, yet it should be made so that it can be worn on most heads, and this is not an easy thing to achieve. A mask may be made to cover only the face of the wearer (fig. 5-A), to cover the face and the top of the head (B), or it may be a headmask, covering the entire head (C) as well as at times including the neck and worn like a helmet with the visor down, the neck of the mask fitting around the head of the wearer (D).

The wearer of the mask must be able to breathe and to see. Consequently, the eyes and nostril orifices should be as wide as it is possible to make them without sacrificing the appearance of the mask. There are, as we see, many practical materials and consequently many ways of making masks, and as modern mask-making is so new it is still in an experimental stage and therefore there is no uniform method. One successful method, developed by the author, is as follows: After the drawings are completed the whole surface of the proposed mask is divided in a number of definite planes which of course will be of various shapes. These planes are then carefully drawn and cut out of Bristol-board or, preferably, the trunkmaker's fibre-board. The diagram (fig. 6) will explain this. The pieces are then glued together with small strips of rough paper or linen on the outside and on the inside. The whole mask thus constructed is then covered with additional layers of paper glued as lightly as possible and subsequently the inside and outside surface is given several coats of varnish and finally, when thoroughly dry, painted with oil colours. Smaller and more realistic masks may be constructed of small pieces of tough paper glued tightly together, starting with stiffer paper and building at first as a foundation a few of the most essential planes of the construction of the head, as for instance forming the forehead of a number of long strips, then the shape of the lower jaws, and a narrow strip, definite and firm, representing the profile, attached to the middle of the forehead and meeting the jaws at the chin. Around these fundamental planes the rest of the mask can be formed, taking care all the time that every bit of paper is tightly glued. Additional layers of the same material will improve the details and will give the mask the desired firmness. Any further improvement of the modelling can be done by cutting off with a razor blade any undesired protuberances and filling with more layers of tiny pieces of paper the cavities that are not wanted. The whole mask is then varnished and painted with oil colours. After it is perfectly dry its surface is still far from being satisfactory. All the defects that could not be seen before the painting are now obvious, and cutting, filling undesired depressions and polishing will be necessary to obtain the desired surface. The sharp incisions will have to be improved if they are clogged by varnish and paint. Then the mask will be ready for final painting.

An easier but less direct and less interesting way of making masks is to begin by modelling the head in clay or plasteline casting the result, and pressing small pieces of paper into the mould, and glueing them securely. This must be done slowly and the paper must be kept as dry as possible to avoid shrinking and warping. Then the rest of the work is the same reinforcing, varnishing, painting, cutting, filling and polishing as in the preceding method.

Modern Uses.—Since the time when the ancient Greek actors appeared masked in the tragedy the use of the masks on the stage has been, with a few exceptions, forgotten in Europe and the drama of our civilized world had no place for it.

Much has been said about the importance of reviving the use of masks on the stage, but the question of how that could be successfully accomplished has been neglected. Attempts at masking one or several actors in a drama for some particular reason or under some special pretext, have been frequent, yet plays that are deliberately and entirely masked, without special reasons, are still a thing of the future. In the spoken drama there is the difficulty that the mask muffles the sound and in other ways interferes with the speech; conversely, the speech spoils the effect of the mask, as one expects the words to be accompanied by the motion of the lips and other facial mobility which are absent in the mask

This difficulty did not exist in the ancient Greek drama where large masks together with the *cothurni* were intended to enhance and magnify the impressiveness of the actor who on the open-air stage was a considerable distance from his audience.

The large mask was not enclosing his face, but was affixed about two inches away from it and he spoke or rather chanted through a funnel which connected his mouth with the wide open mouth of the mask.

(*See* also DRAMA; ACTING; PANTOMIME.) (W. T. B.)

MASKS, GAS. On April 22, 1915, during the World War, Germany used chlorine gas in an attack on Ypres. After the War was over, attempts were made, for instance at the Washington Conference in 1922, to pledge the nations against the use of poison gas but the Abyssinian War has shown that no such pledges are likely to be generally respected by belligerents when once the fighting begins. Various gas masks have been devised, therefore, as a protection against this latest method of attack

The usual gas mask is held tightly over the face. Strong glass spectacles are inserted in the mask which permit of vision. Within the mask, a device completely closes the nostrils.

All inhalation is through a tube held between the teeth and the air so inhaled passes through a receptacle containing the chemicals that counteract the poison gas. Breath is exhaled through the tube and escapes by a valve into the outer air. The receptacle for chemicals and mechanism of the mask is worn under the chin or on the chest

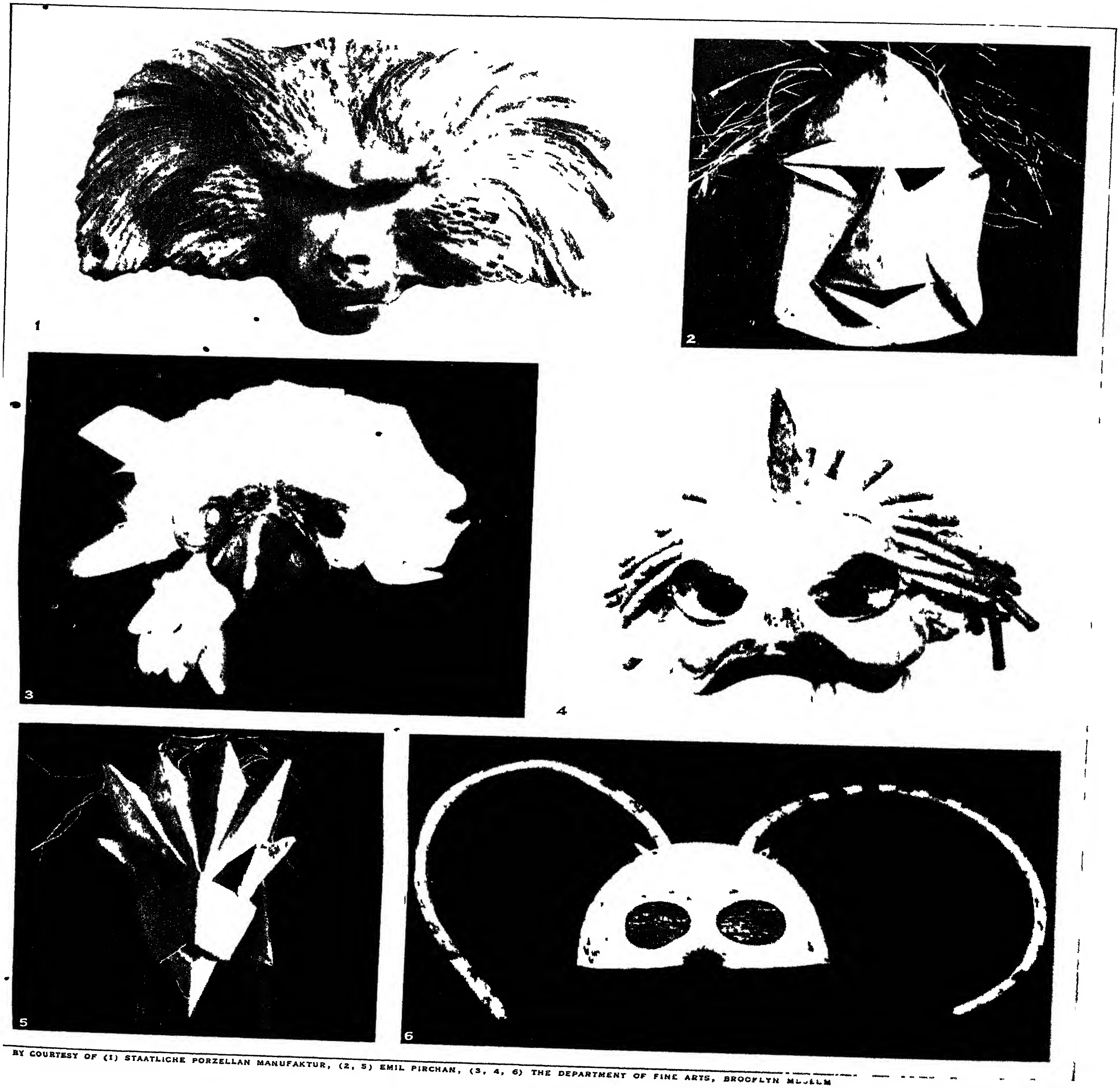
Gas masks are provided for civilians, including children as well as combatants. The storage of the masks, the preservation of their rubber construction and their distribution during an emergency are a new and grave problem of defence.

MASOLINO DA PANICALE (1383-1447), Florentine painter, born at Panicale di Valdelsa, near Florence, is assumed to be identical with Tommaso, son of Aristoforo Fini. He was one of the most distinguished representatives of the Early Renaissance. There is nothing to confirm Vasari's statement that he was a pupil of Lorenzo Ghiberti, but the statement that he studied under Gherardo Starnina, a later Giottesque master, of whom little is known, is not unlikely. In 1423 he was admitted to the guild of *speziali* or druggists, to which painters belonged. The only authenticated works by Masolino were recovered from a coating of whitewash in 1843 at Castiglione d'Olona, near Varese. They consist of two series of frescoes, which he executed for Cardinal Branda Castiglione. The earlier work, in the choir

MODERN MASKS BY BENDA

Three masks by W. T. Benda showing the changes of expression which occur as the head is seen at different inclinations and from various sides

MASKS



BY COURTESY OF (1) STAATLICHE PORZELLAN MANUFAKTUR, (2, 5) EMIL PIRCHAN, (3, 4, 6) THE DEPARTMENT OF FINE ARTS, BROOKLYN MUSEUM

MODERN MASKS

1. Modern mask designed and made by Professor Max Esser
2, 5. Masks made by Emil Pirchan for the Ballet "Die Nachtlichen"; and also used by Harold Kreutzberg in a dance in a Berlin Opera
3, 4, 6. Modern masks designed by Richard Teschner of Vienna

vaulting of the church, represents scenes from the life of the Virgin It is signed "Masolinus de Florentia pinxit," and was probably painted about 1423, when he was 40 years of age.

The later work, in a small baptistery adjoining the church, is dated 1435. These frescoes are adapted to the architecture of the interior. The serene conception, the light and harmonious colour scheme, the graceful movement and expression of the figures are essentially the result of the master's trecentist training, while the attempt, however primitive, to represent three-dimensional space by applying the newly discovered laws of perspective, the study of the nude, and the individual character of the heads are inspired by the incoming Renaissance. The paintings are well preserved and constitute one of the finest monuments of Florentine Art of that time.

Between 1424 and 1426 he worked in the Brancacci chapel, in the church of the Carmine at Florence. As Masaccio and, somewhat later, Filippino Lippi also painted in this chapel, the discussion as to what particular share was done by each still continues, but the following paintings may, with a considerable degree of certainty, be attributed to Masolino: The "Preaching of St. Peter," the "Healing of the Cripple," the "Raising of Tabitha," and the "Fall of Adam and Eve."

He later painted frescoes representing the "Crucifixion" and scenes from the Legends of St. Catherine and of St. Ambrogio, in the church of San Clemente at Rome, for the same Cardinal Branda, for whose Lombard home at Castiglione d'Olona he executed the works described above. The works at San Clemente show the influence of Masaccio, to whom they are sometimes ascribed Among the few panel pictures which may be attributed to Masolino we must mention the two well preserved pictures in the museum at Naples, the "Madonna and Christ in Glory" and the "Founding of S. Maria Maggiore."

Masolino's art shows a constant search after truthful representation Starting from the Giottesque tradition, he took part in the great naturalistic movement emanating from Florence. He probably learned much from his brilliant young pupil, Masaccio, whom he outlived by 20 years. But, while Masaccio belongs entirely to the Renaissance, Masolino never quite freed himself from the traditions of the preceding age

See A H. Layard, *The Brancacci Chapel* (Arundel Society, 1868); P Toesca, *Masolino da Panicale* (1907); Crowe and Cavalcaselle, edit. by L. Douglas, *History of Painting in Italy* (1910). (I. A. R.)

MASON, GEORGE (1725–1792), American statesman, was born in Fairfax county, Va., in 1725. His colonial ancestors held official positions in the civil and military service of Virginia. Mason was a near neighbour and a lifelong friend of George Washington. His large estates and high social standing, together with his personal ability, gave Mason great influence among the Virginia planters, and he became identified with many enterprises, such as the organization of the Ohio company and the founding of Alexandria (1749)

He became a member of the Virginia house of burgesses in 1759 In 1769 he drew up a series of non-importation resolutions which were presented by Washington and adopted by the Virginia legislature. In July 1774 he wrote for a convention in Fairfax county a series of resolutions known as the Fairfax Resolves in which he advocated a congress of the colonies and suggested non-intercourse with Great Britain, a policy adopted by Virginia and later by the Continental Congress. He was a member of the Virginia committee of safety from Aug. to Dec. 1775 and of the Virginia convention in 1775 and 1776. In 1776 he drew up the Virginia Constitution and the famous Bill of Rights, a radically democratic document which had great influence on American political institutions. The Federal Government laid claim to the hinterland; *i.e.*, to territory north and north-west of the Ohio river, which Virginia conceded in 1780 on the basis of a plan worked out by Mason. He was a member of the Virginia house of delegates (1776–88). He took an active part in the Constitutional Convention in Philadelphia in 1787. Particularly notable was his opposition to the compromises in regard to slavery and the slave-trade. Indeed, like most of the prominent Virginians of the time, Mason was strongly in favour of the gradual abolition of slavery. He objected to the large and indefinite powers given by the completed Constitution to Congress, so he joined with Patrick Henry in opposing its ratification in the Virginian convention (1788). Failing in this, he suggested amendments, the substance of several of which was afterwards embodied in the present Bill of Rights. Declining an appointment as a U.S. senator from Virginia, he retired to his home, Gunston Hall (built by him and named after the family home in Staffordshire, England). A radical republican, he believed that local government should be kept strong and central government weak; his democratic theories had much influence in Virginia and other southern and western States. He died on Oct. 7, 1792 at Gunston Hall.

See Kate Mason Rowland, *Life and Writings of George Mason* (1892).

MASON, JAMES MURRAY (1798–1871), American lawyer and political leader, was born in Fairfax county (Va.), on Nov. 3, 1798, the grandson of George Mason (1725–92). Educated at the University of Pennsylvania and the College of William and Mary, he was admitted to the bar in 1820. He was a member of the Virginia house of delegates (1826–32) of the State constitutional convention of 1829, of the national House of Representatives (1837–39) and of the U.S Senate from 1847 until the outbreak of the Civil War when he resigned to take part in the Virginia secession convention. He was a staunch Democrat, upholding States' rights and slavery; the author of the Fugitive Slave Act of 1850.

He was appointed in Aug. 1861 commissioner of the Confederate States to Great Britain The British ship "Trent," upon which he and John Slidell, the commissioner to France, sailed, was intercepted by a U S. ship-of-war, and the two commissioners were seized and carried as prisoners to Boston but were released two months later, through the demands of Great Britain. The incident is well known as the "Trent affair." Arriving at London Mason was unable to secure official recognition, and his commission to Great Britain was withdrawn late in 1863.

He died at Alexandria, Va., on April 28, 1871.

See Virginia Mason (his daughter), *The Public Life and Diplomatic Correspondence of James M. Mason, with some Personal History* (1903).

MASON, SIR JOHN (1503–1566), English diplomatist, was born of humble parentage at Abingdon, and was educated at Oxford, where he became Fellow of All Souls in 1521. Ordained before 1531, he was employed on the continent in collecting information for four successive Tudor sovereigns, and in 1537 became secretary to the English ambassador at Madrid. Under Mary he was appointed in 1553 ambassador at the court of the emperor Charles V, of whose abdication in 1555 he wrote a vivid account. Under Elizabeth, he influenced foreign policy until his death, on April 20, 1566

See J. A. Froude, *History of England* (12 vols., 1856–70); C. Wriothesley, *Chronicle of England during the Reigns of the Tudors*, ed. W. D. Hamilton (Camden Soc., 2 vols., 1875).

MASON, JOHN (1586–1635), founder of New Hampshire, was born in King's Lynn, Norfolk, England. He was governor of the English colony in Newfoundland (1615–21) and published the first map of that region. In 1622 he obtained from the council for New England a grant of the territory (Mariana) between the Salem and Merrimac rivers, and he and Sir Fedinando Gorges received a grant of the region between the Merrimac and Kennebec rivers and extending 60 m. inland (Province of Maine).

In 1629 Mason and Gorges agreed upon a division of the territory held jointly, and Mason received a separate grant of the tract between the Merrimac and the Piscataqua, which he named New Hampshire. With Gorges and a few associates, he also secured a grant of the region named Laconia, including Lake Champlain, and in 1631 the Pescataway grant, bordering on the Piscataqua river. He was vice-president of the council for New England in 1632, and in 1635 was appointed vice-admiral for New England, but died in London in Dec. 1635, before crossing the Atlantic. He was buried in Westminster Abbey.

See *Captain John Mason, the Founder of New Hampshire* (1887,

published by the Prince Society).

MASON, JOHN YOUNG (1799–1859), American political leader and diplomatist, was born in Greensville county (Va.) on April 18, 1799. He served in the Virginia house of delegates (1823–27), in the State constitutional convention (1829–30), the national house of representatives (1831–37), and as judge of the U.S. district court for Virginia (1837–44). From 1844–49 he was a member of the cabinet of both President Tyler and President Polk, as secretary of the navy, serving for an interval as attorney-general. He was president of the Virginia constitutional convention of 1850, and from 1853, was minister to France. He joined with James Buchanan and Pierre Soulé, ministers to Great Britain and Spain respectively, in drawing up (Oct. 1854) the famous Ostend manifesto (*q.v.*). He died at Paris Oct. 3, 1859.

MASON, MAX (1877–), American educationalist and inventor, was born at Madison (Wis.), on Oct. 26, 1877. He graduated from the University of Wisconsin in 1898, continuing his studies at the University of Göttingen. After being instructor in mathematics at the Massachusetts institute of technology 1903–04, he became assistant professor of mathematics at the Sheffield scientific school, Yale university, in 1904. He was appointed professor of mathematical physics at the University of Wisconsin in 1908. He also lectured at Harvard university, 1911–12. During the World War he was a member of the staff of the Naval experimental station, New London (Conn.), and also on the submarine committee of the National research council, 1917–19. He invented several devices for the detection of submarines. He was president of the University of Chicago, 1925–28; he then became director of natural sciences and in 1929 president of the Rockefeller Foundation.

MASON, WILLIAM (1725–1797), English poet, son of William Mason, vicar of Holy Trinity, Hull, was born on Feb. 12, 1725, was educated at St. John's college, Cambridge, and took holy orders. In 1744 he wrote *Musaeus,* a lament for Pope in imitation of *Lycidas,* and in 1749 through the influence of Thomas Gray he was elected a fellow of Pembroke college. He became a devoted friend and admirer of Gray, who addressed him as "Skroddles," and corrected the worst solecisms in his verses. In 1748 he published *Isis,* a poem directed against the supposed Jacobitism of the University of Oxford, which provoked Thomas Warton's *Triumph of Isis.* Mason wrote two plays in a pseudo-classical style: *Elfrida* (1752) and *Caractacus* (1759), produced with some alterations at Covent Garden in 1772 and 1776 respectively. Horace Walpole described *Caractacus* as "laboured, uninteresting, and no more resembling the manners of Britons than of Japanese"; while Gray declared he had read the manuscript "not with pleasure only, but with emotion." Mason received many preferments, including a canonry of York and a prebend of Driffield. When Gray died in 1771 he made Mason his literary executor. In the preparation of the *Life and Letters of Gray,* which appeared in 1774, he had much help from Horace Walpole, with whom he corresponded regularly until 1784, when Mason opposed Fox's India Bill, and offended Walpole by thrusting on him political advice unasked. The correspondence was not renewed until 1795. Mason died at Aston on April 7, 1797.

His poems were collected in 1764 and 1774, and an edition of his *Works* appeared in 1811. His poems with a *Life* are included in Alexander Chalmers's *English Poets.* His correspondence with Walpole was edited by J. Mitford in 1851; and his correspondence with Gray by the same editor in 1853.

MASON AND DIXON LINE, in America, the boundary line (lat. 39° 43′ 26·3″ N.) between Maryland and Pennsylvania, United States; popularly the line separating "free" and "slave" States before the Civil War, and also distinguishing in popular parlance the "North" from the "South," east of the Ohio river. The line derives its name from Charles Mason (1730–87) and Jeremiah Dixon, two English astronomers, whose survey of it to a point about 244m. west of the Delaware between 1763 and 1767 marked the close of the protracted boundary dispute (arising upon the grant of Pennsylvania to William Penn in 1681) between the Baltimores and Penns, proprietors respectively of Maryland and Pennsylvania.

The dispute arose from the designation, in the grant to Penn, of the southern boundary of Pennsylvania mainly as the parallel marking the "beginning of the 40th degree of northerne latitude," after the northern boundary of Maryland had been defined as a line "which lieth under the 40th degree of north latitude from the equinoctial." The eastern part of the line as far as Sideling hill in the western part of the present Washington county, was originally marked with milestones brought from England, every fifth one of which bore on one side the arms of Baltimore and on the other those of Penn; but the difficulties in transporting them to the westward were so great that many were not set up.

The use of the term "Mason and Dixon Line" to designate the boundary between the free and the slave states (and in general between the North and the South) dates from the debates in Congress over the Missouri Compromise in [illegible]. As so used, it may be defined as not only the Mason and Dixon Line proper, but also the line formed by the Ohio river from its intersection with the Pennsylvania boundary to its mouth, thence the eastern, northern and western boundaries of Missouri, and thence westward the parallel 36° 30′—the line established by the Missouri Compromise to separate free and slave territory in the "Louisiana Purchase," except as regards Missouri. (S. L. [illegible])

MASON BEE, the name given to bees of the subfamily Osmiinae (fam. Megachilidae), which construct earthen cells, sometimes mixed with sand, pebbles or wood, each cell containing a single egg, together with honey and pollen as food for the larva. Ten to 20 cells are usually found together. In Europe the commonest genus is *Chalicodoma,* in the United States, *Osmia.* (See BEE, HYMENOPTERA.)

See J. H. Fabre, *Insect Life* (1901).

MASON CITY, a city of northern Iowa, U.S.A., on Lime creek, at an altitude of [illegible] ft.; the county seat of Cerro Gordo county. It is on Federal highways [illegible] and [illegible], and is served by the Chicago and North Western, the Chicago Great Western, the Chicago, Milwaukee, St. Paul and Pacific, the Minneapolis and St. Louis, the Rock Island and electric railways. Pop. ([illegible]) was 20,065 (85% native white), and was [illegible] in [illegible] by Federal census. It is the commercial centre of a rich farming, dairying and stock-raising region. There are valuable deposits of fireclay and sandstone near by, and the city is noted for its hollow building tile and large output of Portland cement ([illegible] bbl. daily). Other important industries are pork packing and the manufacture of beet-sugar ([illegible] lb. annually). The aggregate factory product in [illegible] was valued at $[illegible]. There are 40 wholesale and jobbing houses. Mason City owes its name to the fact that it was settled ([illegible]) by a group of members of the Masonic fraternity. It was incorporated as a town in 1870 and as a city in [illegible]. Since [illegible] it has had a council-manager form of government.

MASONRY, the art of building in stone. The English word "mason" is from the French, which appears in the two forms, *machun* and *masson* (from the last comes the modern French form *maçon,* which means indifferently a bricklayer or mason).

The earliest remains of masonry (apart from the primitive work in rude stone—*see* STONE MONUMENTS; ARCHAEOLOGY, etc.) are those of the ancient temples of India and Egypt. Many of these early works were constructed of stones of huge size, and it still remains a mystery how the ancients were able to quarry and raise to a considerable height above the ground blocks [illegible] or 500 tons in weight. Many of the early buildings of the middle ages were entirely constructed of masses of concrete, often faced with a species of rough cast. The early masonry seems to have been for the most part worked with the axe and not with the chisel. The methods of working and setting stone were much the same as at present, except that owing to difficulties of conveyance the stones were used in much smaller sizes.

Mason's Tools.—The mason's tools may be grouped under five heads—hammers and mallets, saws, chisels, setting-out and setting tools, and hoisting appliances.

There are several different kinds of iron hammers used by the stone worker; the mash hammer has a short handle and heavy head for use with chisels; the iron hammer, used in carving, in shape resembles a carpenter's mallet but is smaller; the waller's

hammer is used for roughly shaping stones in rubble work; the spalling hammer for roughly dressing stones in the quarry; the scabbling hammer, for the same purpose, has one end pointed for use on hard stone; the pick has a long head pointed at both ends, weighs from 14 to 20 lb., and is used for rough dressing and splitting; the axe has a double wedge-shaped head and is used to bring stones to a fairly level face preparatory to their being worked smooth; the patent axe, or patent hammer, is formed with a number of plates with sharpened edges bolted together to form a head; the mallet of hard wood is used for finishing the chisel work and carving; and the dummy is of similar shape but smaller.

A hand saw similar to that used by the carpenter is used for cutting small soft stones. Larger blocks are cut with the two-handed saw worked by two men. For the largest blocks the frame saw is used, and is slung by a rope and pulleys fitted with balance weights to relieve the operator of its weight. The blade is of plain steel, the cutting action being supplied by sand with water as a lubricant constantly applied.

There are, perhaps, even more varieties of chisels than of hammers. The point and the punch have very small cutting edges, a quarter of an inch or less in width. The former is used on the harder and the latter on the softer varieties of stone after the rough hammer dressing. The pitching tool has a wide thick edge and is used in rough dressing. Jumpers are shafts of steel having a widened edge, and are used for boring holes in hard stone. Chisels are made with edges from a quarter-inch to one and a half inches wide; those that exceed this width are termed boasters. The claw chisel has a number of teeth from one-eighth to three-eighths wide, and is used on the surface of hard stones after the point has been used. The drag is a semicircular steel plate, the straight edge having teeth cut in it. It is used to level down the surfaces of soft stones. Cockscombs are used for the same purpose on mouldings and are shaped to various curves.

The implements for setting out the work are similar to those used by the bricklayer and other tradesmen, comprising the rule, square, set square, the bevel capable of being set to any required angle, compasses, spirit level, plumb-rule and bob and mortar trowels. Gauges and moulds are required in sinking moulds to the proper section.

Hoisting Appliances.—The *nippers* (fig. 1), or *scissors*, as they are sometimes termed, have two hooked arms fitting into notches in the opposite sides of the block to be lifted. These arms are riveted together in the same way as a pair of scissors, the upper ends having rings attached for the insertion of a rope or chain which when pulled tight in the operation of lifting causes the hooked ends to grip the stone. *Lewises* (fig. 2) are wedge-shaped pieces of steel which are fitted into a dovetailed mortise in the stone to be hoisted. They are also used for setting blocks too large to be set by hand, and are made in several forms.

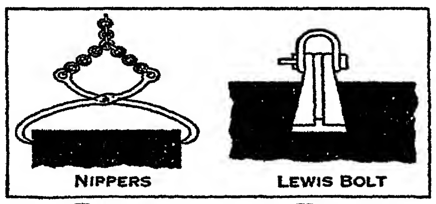


FIG. 1 FIG. 2

Scaffolding.—For rubble walls, single scaffolds, resting partly on the walls, similar to those used for brickwork (*q.v.*), are employed; for ashlar and other gauged stonework (*see* below) self-supporting scaffolds are used with a second set of standards and ledgers erected close to the wall, the whole standing entirely independent. The reason for the use of this double scaffold is that otherwise holes for the putlogs to rest in would have to be left in the wall, and obviously in an ashlar stone wall it would be impossible properly to make these good on the removal of the scaffold (*see* further SCAFFOLD).

Seasoning.—Stone freshly quarried is full of sap, and thus admits of being easily worked. On being exposed to the air the sap dries out, and the stone becomes much harder in consequence. For this reason, and because carriage charges are lessened by the smaller bulk of the worked stone as compared with the rough block, the stone for a building is often specified to be quarry-worked. In the erection of St. Paul's cathedral, Sir Christopher Wren required that the stone after being quarried should be exposed for three years on the sea-beach before use.

Setting.—All beds and joints should be truly worked and perfectly level. If the surface be convex it will give rise to wide unsightly joints; if concave the weight thrown on the stone will rest on the edges and probably cause them to "flush" or break off and disfigure the work. Large stones are placed in position with the aid of hoisting appliances and should be tried in position before being finally set. Great care should be taken to avoid fracturing or chipping the stone in the process of handling, as it is impossible to make good such damage. All stratified stones—and this includes by far the largest proportion of building stones—when set in a level position should be laid on their natural bed, *i.e.*, with their laminae horizontal. The greatest strength of a stone is obtained when the laminae lie at right angles to the pressure placed upon it. In the case of arches these layers should be parallel with the centre line of the voussoirs and at right angles to the face of the arch. For cornices (except the corner-stones) and work of a like nature, the stone is set with the laminae on edge and perpendicular to the face of the work. With many stones it is easy to determine the bed by moistening with water, when the laminae will become apparent. Some stones, however, it is impossible to read in this way, and it is therefore advisable to have them marked in the quarry.

For the shafts of columns especially it is necessary to have the layers horizontally placed, and a stone should be selected from a quarry with a bed of the required depth.

Of whatever quality the stone may be of which a wall is built, it should consist as much of stone and as little of mortar as possible. Only fine mortar is admissible if we are to obtain as thin joints as possible. The joints should be well raked out and pointed in Portland cement mortar. This applies only to some sandstones, as marbles and many limestones are stained by the use of Portland cement. For these a special cement must be employed, composed of plaster of Paris, lime and marble or stone-dust.

Bond is of not less importance in stone walling than in brickwork. In ashlar-work the work is bonded uniformly, the joints being kept perpendicularly one over the other; but in rubble-work, instead of making the joints recur one over the other in alternate courses they should be carefully made to lock, so as to give the strength of two or three courses or layers between a joint in one course and the joint that next occurs vertically above it in another course. In the through or transverse bonding of a wall a good proportion of header stones running about two-thirds of the distance through the width of the wall should be provided to bind the whole structure together. The use of through stones, *i.e.*, stones running through the whole thickness of the wall from front to back, is not to be recommended. Such stones are liable to fracture and convey damp to the internal face.

As with brickwork so in masonry great care must be exercised to prevent the different parts of a building settling unequally. When two portions of a building differing considerably in height come together, it is usual to employ a slip or housed joint instead of bonding the walls into each other. This arrangement allows the heavier work to settle to a greater extent than the low portion without causing any defect in the stones.

The footings of stone walls should consist of large stones of even thickness proportionate to their length; if possible they should be the full breadth in one piece. Each course should be well bedded and levelled.

Rubble and Ashlar.—There are, broadly speaking, two classes of stone walling: rubble and ashlar. Rubble walls are built of stones more or less irregular in shape and size and coarsely jointed. Ashlar walls are constructed of carefully worked blocks of regular dimensions and set with fine joints.

Random rubble (fig. 3) is the roughest form of stonework. It is built with irregular pieces of stone usually less than 9in. thick, loosely packed without much regard to courses, the interstices between the large stones being occupied by small ones, the remaining crevices filled up with mortar. Bond stones or headers should be used frequently in every course. This form of walling is much used in stone districts for boundary walls and is often set dry

without mortar. For this work the mason uses no tool but the trowel to lay on the mortar, the scabbling hammer to break off the most repulsive irregularities from the stone, and the plumb-rule to keep his work perpendicular.

Coursed rubble (fig. 4) is levelled up in courses 12 or 18in. deep, the depth varying in different courses according to the sizes of the stones. The stones are dressed by the workman before he begins building, to obtain a level bed and perpendicular face.

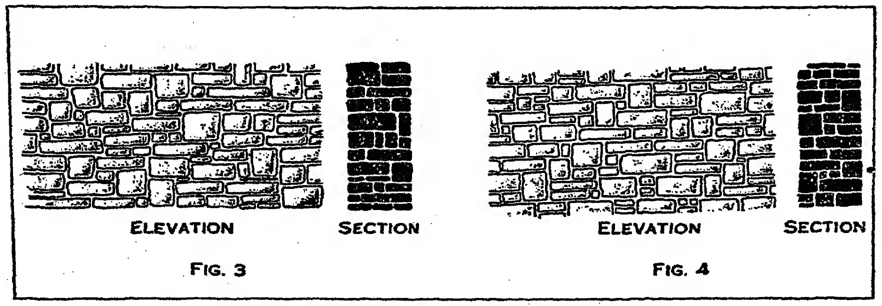


FIG. 3.—RANDOM RUBBLE WALLING
FIG. 4.—COURSED RUBBLE WALLING

Irregularly coursed squared rubble is a development of uncoursed random rubble, the stones in this case being squared with the hammer and roughly faced up with the axe. The courses jump from one level to another as the sizes of the blocks demand; the interstices are filled in with small pieces of stone called "snecks."

For coursed squared rubble the stone is faced in a similar manner and set in courses, the depth of each course being made up of one or more stones. In regular coursed rubble all the stones in one course are of the same height.

Block-in-course is the name applied to a form of stone walling that has some of the characteristics of ashlar but the execution of which is much rougher. The courses are usually less than 12in. high. It is much used by engineers for waterside and railway work where a good appearance is desired.

The angles or quoins of rubble-work are always carefully and precisely worked and serve as a gauge for the rest of the walling. Frequently, the quoins and jambs are executed in ashlar, which gives a neat and finished appearance and adds strength to the work.

The name ashlar is given, without regard to the finish of the face of the stone, to walling composed of stones carefully dressed, from 12 to 18in. deep, the mortar joints being about an eighth of an inch or less in thickness. No stone except the hardest should exceed in length three times its depth when required to resist a heavy load and its breadth should be from one and a half to three times its depth. The hardest stone may have a length equal to four or perhaps five times its depth and a width three times its depth. The face of ashlar-work may be plain and level, or have rebated, chamfered or moulded joints.

Backing to Stonework.—The great cost of this form of stone-work renders the employment of a backing of an inferior nature very general. This backing varies according to the district in which the building operations are being carried on, being rubble stonework in stone districts and brick or concrete elsewhere, the whole being thoroughly tied together both transversely and longitudinally with bondstones. In England a stone much used for backing ashlar and Kentish rag rubble-work is a soft sandstone called "hassock." In the districts where it is quarried it is much cheaper than brickwork. (For brickbacking *see* BRICKWORK.) Ashlar facing usually varies from 4 to 9in. in thickness. The work must not be all of one thickness, but should vary in order that effective bond with the backing may be obtained. If the work is in courses of uneven depth the narrow courses are made of the greater thickness and the deep courses are narrow. It is sometimes necessary to secure the stone facing back with iron ties, but this should be avoided wherever possible, as they are liable to rust and split the stonework. When it is necessary to use them they should be covered with some protective coating. The use of a backing to a stone wall, besides lessening the cost, gives a more equable temperature inside the building and prevents the transmission of wet by capillary attraction to the interior.

All work of this description must be executed in Portland cement, mortar of good strength, to avoid as much as possible the unequal settlement of the deep courses of stone facing and the narrower courses of the brick or rough stone backing. If the backing is of brick it should never be less than 9in. thick, and whether of stone or brick it should be levelled up in courses of the same thickness as the ashlar.

Walling.—There are many different sorts of walling, or modes of structure, arising from the nature of the materials available in various localities. That is, perhaps, of most frequent occurrence in which either squared, broken or round flints are used. This, when executed with care, has a distinctly decorative appearance. To give stability to the structure, lacing courses of tiles, bricks or dressed stones are introduced, and brick or stone piers are built at intervals, thus forming a flint panelled wall. The quoins, too, in this type of wall are formed in dressed stone or brickwork.

Uncoursed rubble built with irregular blocks of ragstone, as unstratified rock quarried in Kent, is in great favour for facing the external walls of churches and similar works.

Pointing.—As with brickwork this is generally done when the work is completed and before the scaffolding is removed. Suitable weather should be chosen, for if the weather be either frosty or too hot the pointing will suffer. The joints are raked out to a depth of half an inch or more, well wetted, and then refilled with a fine mortar composed specially to resist the action of the weather. This is finished flat or compressed with a special tool to a shaped joint, the usual forms of which are shown in fig. 5.

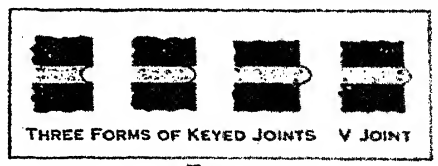


FIG. 5

To give a uniform appearance to the stonework and preserve the finished face until a hardened skin has formed, it is usual to coat the surface of exposed masonry with a protective compound of ordinary limewhite with a little size mixed in it, or a special mixture of stone-dust, lime, salt, whiting and size with a little ochre to tone it down. After six months or more the work is cleaned down with water and stiff bristle or wire brushes. Sometimes muriatic acid much diluted with water is used.

Technical Terms.—Of the following technical terms, many will be found embodied in the drawing of a gable wall (fig. 6), which shows the manner and position in which many different members are used.

Apex Stone.—The topmost stone of a gable forming a finial for the two sloping sides; it is also termed a "saddle" (fig. 6).

Blocking Course, a heavy course of stone above a cornice to form a parapet and weigh down the back of the cornice (fig. 7).

Bed.—The *bed* surface upon which a stone is set or bedded should be worked truly level in every part. Many workmen to form a neat thin joint with a minimum amount of labour hollow the bed and thus when the stone is set all weight is thrown upon the edges with the frequent result that these are crushed.

Coping.—The *coping* or *capping* stones are placed on the top of walls not covered by a roof, spanning their entire width and throwing off the rain and snow, thus keeping the interior of the wall dry. The fewer the number of joints the better the security, and for this reason it is well to form copings with as long stones as possible. To throw water off clear, and prevent it from running down the face of the wall, the coping should project an inch or two on each side and have a throat worked on the underside of the projections (fig. 6).

Cornice, a projecting course of moulded stone crowning a structure, forming a cap or finish and serving to throw any wet clear of the walls. A deep drip should always be worked in the upper members of a cornice to prevent the rain trickling down and disfiguring the moulding and the wall (fig. 7).

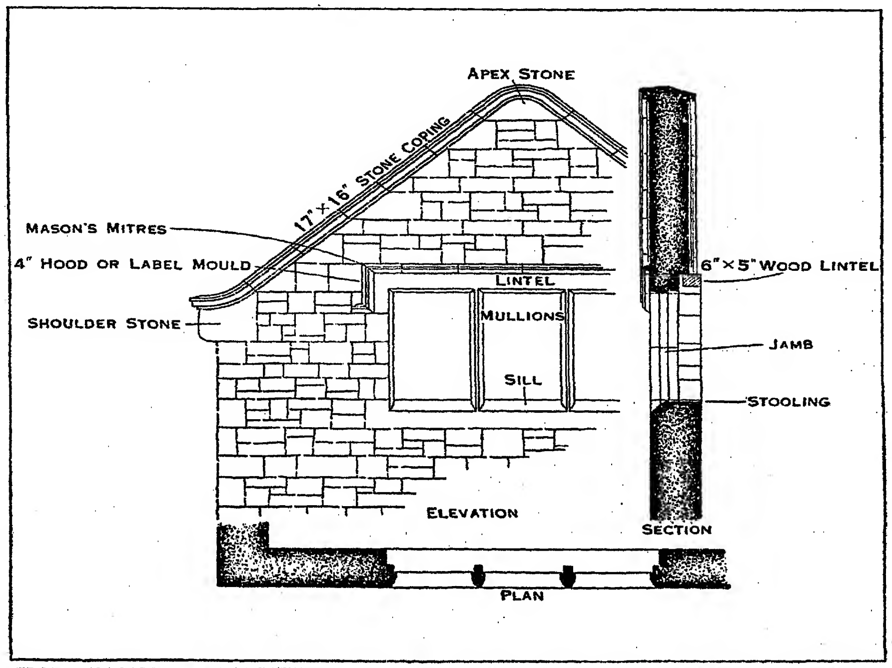
Corbel, a stone built into a wall and projecting to form a cantilever, supporting a load beyond the face of the wall.

Skew Corbel, a stone placed at the base of the sloping side of a gable wall to resist any sliding tendency of the sloping coping.

Stones placed for a similar purpose at intervals along the sloping side, tailing into the wall, are termed "kneelers" and have the section of the coping worked upon them.

Corbel Table, a line of small corbels placed at short distances apart supporting a parapet or arcade. This forms an ornamental feature which was much employed in early Gothic times. It probably originates from the machicolations of ancient fortresses.

Dressings, the finished stones of window and door jambs and quoins. For example, a "brick building with stone dressings"



FROM JAGGARD "ARCHITECTURAL AND BUILDING CONSTRUCTION PLATES" (CAMBRIDGE UNIVERSITY PRESS)

FIG. 6

would have brick walls with stone door and window jambs, heads and sills, and perhaps also stone quoins.

Diaper, a square pattern formed on the face of the stonework by means of stones of different colours and varieties or by patterns carved on the surface.

Finial, a finishing ornament applied usually to a gable end.

Gablet, small gable-shaped carved panels frequently used in Gothic stonework for apex stones, and in spires, etc.

Gargoyle, a detail, not often met with in modern work, which consists of a waterspout projecting so as to throw the rain-water from the gutters clear of the walls. In early work it was often carved into grotesque shapes of animal and other forms.

Galleting.—The joints of rubble are sometimes enriched by having small pebbles or chips of flint pressed into the mortar whilst green. The joints are then said to be "galleted."

Jamb.—Window and door jambs should always be of dressed stone, both on account of the extra strength thus gained and in order to give a finish to the work. The stones are laid alternately as stretchers and headers; the former are called outbands, the latter inbands (fig. 6).

Label Moulding, a projecting course of stone running round an arch. When not very large it is sometimes cut on the voussoirs, but is usually made a separate course of stone. Often, and especially in the case of door openings, a small sinking is worked on the top surface of the moulding to form a gutter which leads to the sides any water that trickles down the face of the wall.

Lacing Stone.—This is placed as a voussoir in brick arches of wide span, and serves to bond or lace several courses together.

Lacing Course, a course of dressed stone, bricks or tiles, run at intervals in a wall of rubble or flint masonry to impart strength and tie the whole together (fig. 6).

Long and Short Work, a typical Saxon method of arranging quoin stones, flat slabs and long narrow vertical stones being placed alternately. Earls Barton church in Northamptonshire is an example of their use in old work. In modern work, long and short work, also termed "block and start," is little used (fig. 6).

Parapet, a fence wall at the top of a wall at the eaves of the roof. The gutter lies behind, and waterways are formed through the parapet wall for the escape of the rain-water.

Plinth, a projecting base to a wall serving to give an appearance of stability to the work.

Quoin, the angle at the junction of two walls. Quoins are often executed in dressed stone.

Rag-bolt, the end of an iron bolt when required to be let into stone is roughed or ragged. A dovetailed mortise is prepared in the stone and the ragged end of the bolt placed in this, and the mortise filled in with molten lead or sand and sulphur (fig. 8).

Sill, the stone which forms a finish to the wall at the bottom of an opening. Sills should always be weathered, slightly in the case of door sills, more sharply for windows, and throated on the underside to throw off the wet. The weathering is not carried through the whole length of the sill, but a stool is left on at each end to form a square end for building in (fig. 6).

String Courses (*q.v.*) are horizontal bands of stone, either projecting beyond or flush with the face of the wall.

Scontions are the dressed stones forming the inside angles of the jamb of a window or door opening.

Spalls, small pieces chipped off whilst working a stone.

Templates, slabs of hard stone set in a wall to take the ends of a beam or girder so as to distribute the load over a larger area of the wall.

Throat, a groove worked on the underside of projecting external members to intercept rain-water and cause it to drop off the member clear of the work beneath (fig. 7).

Weathering.—The surface of an exposed stone is weathered when it is worked to a slope so as to throw off the water. Cornices, copings, sills and string courses should all be so weathered.

Methods of Finishing Face of Stones.—The *self face* or *quarry face* is the natural surface formed when the stone is detached from the mass in the quarry or when a stone is split.

Saw-face, the surface formed by sawing.

Hammer-dressed, Rock-faced or Pitch-faced.—This face is used for ashlar-work, usually with a chisel-draughted margin around each block. It gives a very massive and solid appearance, and is, therefore, the cheapest face to adopt for ashlar-work (fig. 6).

Broached and Pointed Work.—This face is also generally used with a chisel-draughted margin. The stone as left from the

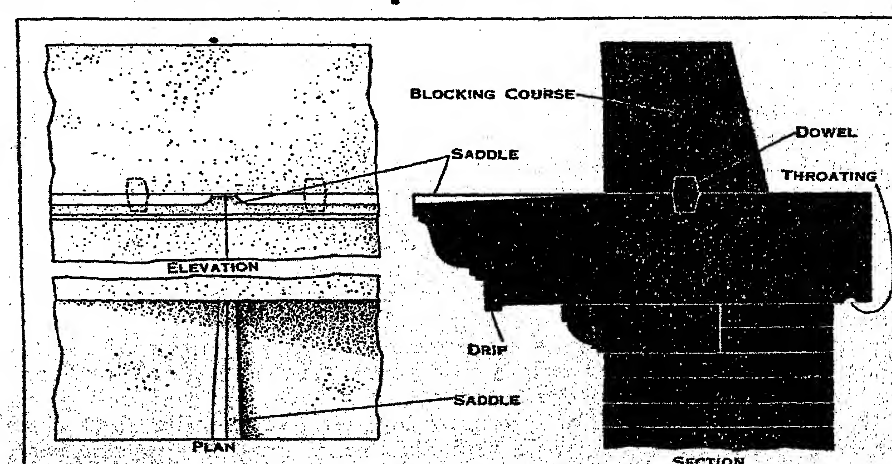
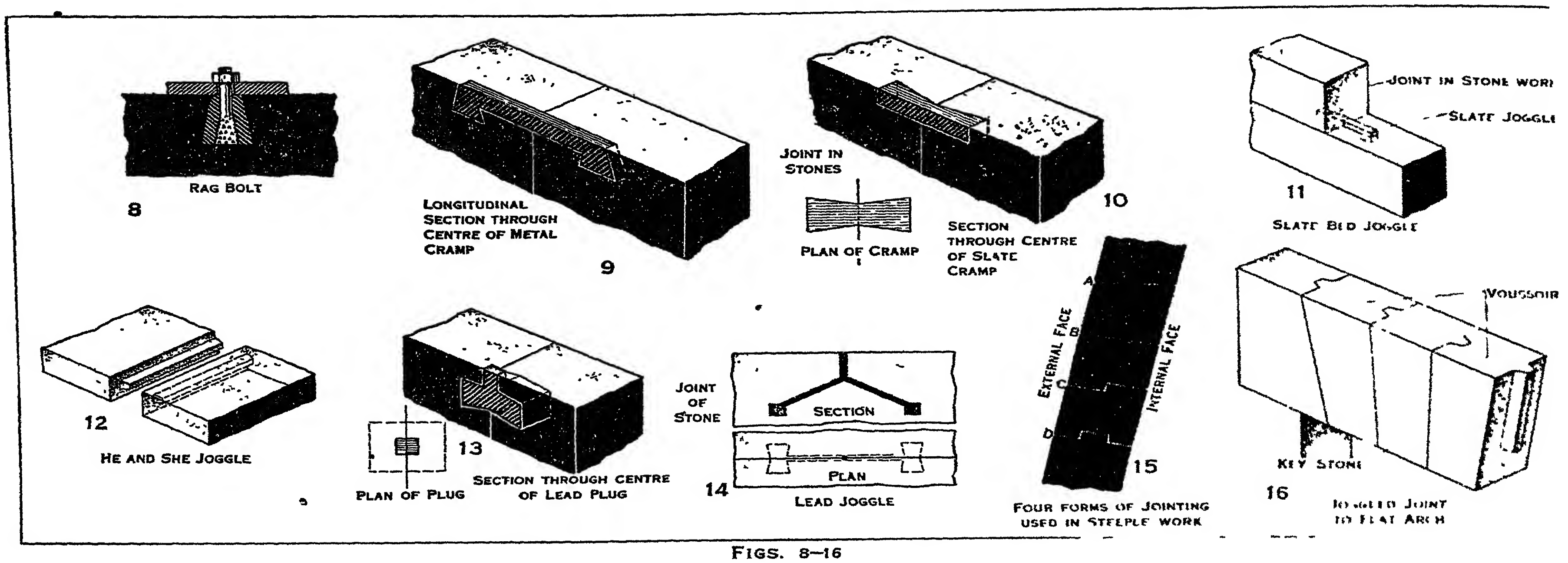


FIG. 7

scabbling hammer at the quarry has its rocky face worked down to an approximate level by the point. In broached work the grooves made by the tool are continuous, often running obliquely across the face of the block. In pointed work the lines are not continuous; the surface is rough or fine pointed according as the point is used over every inch or half-inch of the stone. The point is used more upon hard stones than soft ones (fig. 6).

Tooth-chiselled Work.—The cheapest method of dressing soft



Figs. 8–16

stones is by the toothed chisel which gives a surface very much like the pointed work of hard stones.

Droved Work.—This surface is obtained with a chisel about two and a half inches wide, no attempt being made to keep the cuts in continuous lines.

Tooled Work is somewhat similar to droved work and is done with a flat chisel, the edge of which is about four inches wide, care being taken to make the cuts in continuous lines across the width of the stone.

Combed or Dragged Work.—For soft stones the steel comb or drag is often employed to remove all irregularities from the face and thus form a fine surface. These tools are specially useful for moulded work, as they are formed to fit a variety of curves.

Rubbed Work.—For this finish the surface of the stone is previously brought with the chisel to a level and approximately smooth face, and then the surface is rubbed until it is quite smooth with a piece of gritstone aided by fine sand and water as a lubricant. Marbles are polished by being rubbed with gritstone, then with pumice, and lastly with emery powder.

Besides these, the most usual methods of finishing the faces of stonework, there are several kinds of surface formed with hammers or axes of various descriptions.

The *toothed axe* has its edges divided into teeth, fine or coarse, according to the work to be done. It is used to reduce the face of limestones and sandstones to a condition ready for the chisel. The *bush hammer* has a heavy square-shaped double-faced head, upon which are cut projecting pyramidal points. It is used to form a surface full of little holes, and with it the face of sand and limestones may be brought to a somewhat ornamental finish. The *patent hammer* is used on granite and other hard rocks, which have been first dressed to a medium surface with the point. The fineness of the result is determined by the number of blades in the hammer, and the work is said to be "six-," "eight-," or "ten-cut" work according to the number of blades inserted or bolted in the hammer head. The *crandall* has an iron handle slotted at one end with a hole ⅜in. wide and 3in. long. In this slot are fixed by a key ten or 11 double-headed points of ¼in. square steel about 9in. long. It is used for finishing sandstone and soft stones after the surface has been levelled down with the axe or chisel. It gives a fine pebbly sparkling appearance.

Vermiculated Work.—This is formed by carving a number of curling worm-like lines over the face of the block, sinking in between the worms to a depth of a fourth of an inch. The surface of the strings is worked smooth, and the sinkings are pock-marked with a pointed tool.

Furrowed Work.—In this face the stone is cut with a chisel into a number of small parallel grooves or furrows (fig. 6).

Reticulated Face is a finish somewhat similar to vermiculated work, but the divisions are more nearly square.

Face Joints of Ashlar.—The face joints of ashlar stonework are often sunk or rebated to form what are termed rusticated joints; sometimes the angles of each block are moulded or chamfered to give relief to the surface or to show a [illegible] effect.

Joints in Stonework.—The joints between one block of stone and another are formed in many ways by cramps, dowels and joggles of various descriptions, several of the most common of which are illustrated in figs. 8–16.

Cramps and Dowels.—The stones of copings, cornices and works of a similar nature, are often tied together with metal cramps to check any tendency of the stones to separate under the force of the wind (figs. 9 and 10). Cramps are made of iron (plain or galvanized), copper or gun-metal, of varying sections and lengths to suit the work. A typical cramp would be about 9in. long, 1 or 1½in. wide and from [illegible] to [illegible] thick and turned down about 1½in. at each end. A dovetailed mortise is formed at a suitable point in each of the stones to be joined and connected by a chase. The cramp is placed in the channel with its turned-down ends in the mortises, and it is then fixed with molten lead, sulphur and sand, or Portland cement. Lead heals on cooling, and if used at all should be well caulked when cold. Double dovetailed slate cramps bedded in Portland cement are occasionally used (fig. 10).

Dowels are used for connecting stones where the use of cramps would be impracticable, as in the joints of window mullions, the shafts of small columns, and in similar works.

Joggles.—There are many ways of making a joggle joint. The joggle may be worked on one of the stones so as to fit into a groove in the adjoining stone, or grooves may be cut in both the stones and an independent joggle of slate, pebbles or Portland cement fitted, the joggle being really a kind of dowel. The pebble joggle joint is formed with the aid of pebbles as small dowels fitted into mortises in the jointing faces of two stones and set with Portland cement; but joggles of slate have generally taken the place of pebbles. Portland cement joggles are formed by pouring cement grout into a vertical or oblique mortise formed by cutting a groove in each of the joining surfaces of the stone. What is known as a he-and-she joggle, worked on the edges of the stones themselves, is shown in fig. 12.

Plugs or dowels of lead are formed by pouring molten lead through a channel into dovetailed mortises in each stone (figs. 13 and 14). When cold the metal is caulked to compress it tightly into the holes.

The saddle joint is used for cornices, and is formed when a

portion of the stone next the joint is left raised so as to guide rain-water away from the joint (fig. 7).

Two forms of rebated joints for stone copings and roofs are common. In one form (shown in fig. 6) the stones forming the coping are thicker at their lower and rebated edge than at the top plain edge, giving a stepped surface. The other form has a level surface and the stone is of the same thickness throughout and worked to a rebate on top and bottom edges. In laying stone roofs the joints are usually lapped over with an upper slab.

Joints in Spires.—Four forms of jointing for the battering stonework of spires are shown in fig. 15. A is a plain horizontal joint. B is a similar joint formed at right angles to the face of the work. This is the most economical form of joint, the stone being cut with its sides square with each other; but if the mortar in the joint decay, moisture is allowed to penetrate. With these forms dowelling is frequently necessary for greater stability. The joints C and D are more elaborate and much more expensive on account of the extra labour involved in working and fitting.

Where a concentrated weight is carried by piers or columns the bed joints are in many cases formed without the use of mortar, a thin sheet of milled lead being placed between the blocks of stone to fill up any slight inequalities.

Moulded Work.—The working of mouldings in stone is an important part of the mason's craft, and forms a costly item in the erection of a stone structure. Much skill and care is required to retain the arrises sharp and the curved members of accurate and proportionate outline. As in the case of wood mouldings, machinery now plays an important part in the preparation of stone moulded work. The process of working a stone by hand labour is as follows: The profile of the moulding is marked on to a zinc template on opposite ends of the stone to be worked; a short portion, an inch or two in length, termed a "draught," is at each end worked to the required section. The remaining portion is then proceeded with, the craftsman continually checking the accuracy of his work with a straight-edge and zinc templates. A stone to be moulded by machinery is fixed to a moving table placed under a shaped tool which is fixed in an immovable portion of the machine, and is so adjusted as to cut or chip off a small layer of stone. Each time the stone passes under the cutter it is automatically moved a trifle nearer, and thus it gradually reduces the stone until the required shape is attained.

Iron in Stonework.—The use of iron dowels or cramps in stonework, unless entirely and permanently protected from oxidation, is attended by the gravest risks; for upon the expansion of the iron by rusting the stone may split, and perhaps bring about a more or less serious failure in that portion of the building. A case in point is that of the church of St. Mary-le-Strand, London, where the ashlar facing was secured to the backing with iron cramps; these were inefficiently protected from damp and many of the blocks have been split from rusting. Smeaton in his Eddystone lighthouse used dowels of Purbeck marble.

Stone Arches.—Stone arches are very frequently used both in stone and brick buildings. (*See* ARCH; for general definitions and terms *see* BRICKWORK.)

Stone Tracery; Carving.—The designs of Gothic and other tracery stonework are almost infinite, and there are many methods, ingenious and otherwise, of setting out such work. Nearly all diagrams of construction are planned on the principle of geometrical intersections, and the jointing is a matter which must be carefully considered in order to avoid any waste of stone or labour.

Ordinarily in stone tracery the joints should be "mason's joints"; that is to say, the moulding is stopped and returned, the joint being at right angles to a member when it occurs in a straight part of a member and, when it occurs in a curved member, being a continuation of the radius or the mean of the continuation of the two radii. In stone-work the joints are not "scribed" or "mitred" as in joinery. All the upper construction of windows and doors and of aisle arches should be protected from superincumbent pressure by strong relieving arches above the labels, which should be worked with the ordinary masonry, and so set that the weight above should avoid pressure on the fair work, which would be liable to flush the joints of the tracery.

Stone carving is a craft quite apart from the work of the ordinary stonemason, and like carving in wood needs an artistic feeling and special training. Carving-stone should be of fine grain and sufficiently soft to admit of easy working. The Bath stones in England and the Caen stone of France are largely used for internal work, but if for the exterior they should be treated with some chemical preservative. Carving is frequently done after the stone is built into position, the face being left rough—"boasted"—and projecting sufficiently for the intended design.

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MASPERO, GASTON CAMILLE CHARLES (1846–1916), French Egyptologist, was born in Paris on June 23, 1846, his parents being of Lombard origin. He was in his second year at the École Normale in 1867 when he met Mariette, who was then in Paris as commissioner for the Egyptian section of the exhibition. Mariette encouraged his studies, and in 1869 he became a teacher (*répétiteur*) of Egyptian language and archaeology at the École des Hautes Études; in 1874 he was appointed to the chair of Champollion at the Collège de France.

In Nov. 1880 Professor Maspero went to Egypt as head of an official archaeological mission, which ultimately developed into the well-equipped Institut Français de l'Archéologie Orientale. Maspero then succeeded as director-general of excavations and of the antiquities of Egypt. He held this post till June 1886; in these five years he had organized the mission, and had discovered the great cache of royal mummies at Deir el-Bahri in July 1881. Maspero now resumed his professorial duties in Paris until 1899, when he returned to Egypt in his old capacity as director-general of the department of antiquities. He found the collections in the Cairo museum enormously increased, and he superintended their removal from Gizeh to the new quarters at Kasr en-Nil in 1902. The vast catalogue of the collections made rapid progress under Maspero's direction. Twenty-four volumes or sections were already published in 1909. The repairs and clearances at the temple of Karnak led to the most remarkable discoveries in later years (*see* KARNAK). He died in Paris on June 30, 1916.

Among his best-known publications are: *Histoire ancienne des peuples de l'Orient classique* (3 vols., Paris, 1895–97), displaying the history of the whole of the nearer East from the beginnings to the conquest by Alexander; a smaller *Histoire des peuples de l'Orient*, 1 vol., of the same scope, which has passed through six editions from 1875 to 1904; *Études de mythologie et d'archéologie égyptiennes* (1893, etc.), a collection of reviews and essays originally published in various journals, and especially important as contributions to the study of Egyptian religion; *L'Archéologie égyptienne* (latest ed., 1907), of which several editions have been published in English.

Maspero also wrote: *Les Inscriptions des pyramides de Saqqarah* (Paris, 1894); *Les Momies royales de Deir el-Bahari* (1889); *Les Contes populaires de l'Égypte ancienne* (3rd ed., 1906); *Causeries d'Égypte* (1907), translated by Elizabeth Lee as *New Light on Ancient Egypt* (1908).

MASQUERADE, a form of entertainment or a costume ball where the personages are masked or disguised. The abbreviated form of the word, "masque" or "mask" (*q.v.*), applies more particularly to certain varieties of drama which flourished during Elizabethan times. *See* DRAMA.

MASS, a name for the Christian eucharistic service, practically confined since the Reformation to that of the Roman Catholic Church. (Eccl. Lat. *Missa.*) The various orders for the celebration of Mass are dealt with under LITURGY; a detailed account of the Roman order is given under MISSAL; and the general development of the eucharistic service, including the mass, is described in the article EUCHARIST. In the 4th century *Pilgrimage of Etheria* (*Silvia*) the word *missa* is used indiscriminately of the Eucharist, other services, and the ceremony of dismissal. F. Kattenbusch (Herzog-Hauck, *Realencyklop. s.v.* "Messe") ingeniously, but with little evidence, suggests that the word may have had a double

origin and meaning: (1) in the sense of *dimissio*, "dismissal"; (2) in that of *commissio* "commission," "official duty," *i.e.*, the exact Latin equivalent of the Greek λειτουργία (*see* LITURGY), and hence the conflicting use of the term. It is, however, far more probable that it was a general term that gradually became crystallized as applying to that service in which the dismissal represented a more solemn function. In the narrower sense of "Mass" it is first found in St. Ambrose (*Ep.* 20, 4, ed. Ballerini) where the *Missa* is identified with the sacrifice. It continued, however, to be used loosely, though its tendency to become proper only to the principal Christian service is clear from a passage in the 12th homily of Caesarius, bishop of Arles (d. 542). (*See* also Isadore of Seville, *Etym.* v. 19.)

Whatever its origin, the word Mass had by the time of the Reformation been long applied only to the Eucharist; and, though in itself a perfectly colourless term, and used as such during the earlier stages of the 16th century controversies concerning the Eucharist, it soon became identified with that sacrificial aspect of the sacrament of the altar which it was the chief object of the reformers to overthrow. In England, so late as the first Prayer Book of Edward VI. it remained one of the official designations of the Eucharist, which is there described as "The Supper of the Lorde and holy Communion, commonly called the Masse." Bishops Ridley and Latimer denounced "the Mass" with unmeasured violence; Latimer said of "Mistress Missa" that "the devil hath brought her in again"; Ridley said "I do not take the Mass as it is at this day for the communion of the Church, but for a popish device," etc. (*Works*, ed. Parker Soc. pp 120, *seq.*). Clearly the word mass had ceased to be a colourless term generally applicable to the eucharistic service; it was, in fact, not only proscribed officially, but in the common language of English people it passed entirely out of use except in the sense in which it is defined in *Johnson's Dictionary, i.e.*, that of the "Service of the Romish Church at the celebration of the Eucharist." In connection with the Catholic reaction in the Church of England, which had its origin in the "Oxford Movement" of the 19th century, efforts have been made by some of the clergy to reintroduce the term "Mass" for the Holy Communion in the English church.

See Du Cange, *Glossarium, s.v.* "Missa"; F Kattenbusch in Herzog-Hauck, *Realencyklopädie* (ed. 1903) *s.v.* "Messe, dogmengeschichtlich." Fortesque, *Catholic Encyclopaedia* vol. ix. *s.v.* "Mass." For the facts as to the use of the word "mass" at the time of the Reformation *see* the article by J H. Round in the *Nineteenth Century* for May, 1897. (*See* ART, MUSIC.) (A. N. J. W.)

MASS IN MUSIC

Musical settings of the Mass are of central importance in the history of music during the 15th and 16th centuries.

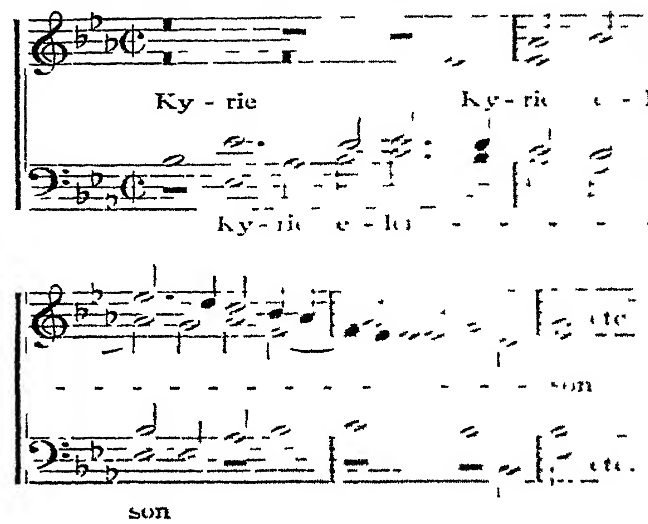
1. **Polyphonic Masses.**—As an art-form the musical Mass is governed by the structure of its text. The supremely important parts of the Mass are those which have the smallest number of words, namely the opening *Kyrie;* the *Sanctus* and *Benedictus,* embodying the central acts and ideas of the service; and the concluding *Agnus Dei.* A 16th century composer could best write highly developed music when words were few and such as would gain rather than lose by repetition. Now the texts of the *Gloria* and *Credo* were more voluminous than any others which 16th century composers attempted to handle in a continuous scheme. The practical limits of the Church service made it impossible to break them up by setting each clause to a separate movement, a method by which Josquin and Lasso contrived to fill a whole hour with a penitential psalm. Accordingly the great masters evolved for the *Gloria* and *Credo* a style midway between that of the elaborate motet (adopted in the *Sanctus*) and the homophonic reciting style of the Litany.

This gave the Mass a range of style which made it to the 16th century composer what the symphony is to the great instrumental classics. Moreover, as being inseparably associated with the highest act of worship, it severely tested the composer's depth and truthfulness of expression. The story of archaic and decadent corruptions in polyphonic Masses is touched upon elsewhere. (*See* MUSIC, section 3, and PALESTRINA.) In the 20th century a decree of Pius X. again inculcated the restoration of the Palestrina style to its proper position in liturgical music. But the trouble with modern settings of the Mass is not the decadence of an old art but a fundamental incompatibility between the modern orchestra and a good liturgical style.

The 16th century Mass was often written for a definite day, and when the composer bases its theme on those of his setting of an appropriate motet (*q.v.*) for that day, the whole musical

Themes of Victoria's *Missa O quam gloriosum est regnum* The words quoted above each theme are those of the motet of the same name. See illustration to MOTET

I *Kyrie* ("In quo cum Christi")



Also recognizable in the Gloria at "in gloria Dei Patris," in the Credo at "et vitam venturi saeculi," and in the Agnus Dei at "Qui tollis peccata mundi."

service becomes a single tissue of significant themes. Thus, Victoria wrote for All Saints' Day a motet *O quam gloriosum est regnum*, and a Mass with the same title and on the same themes. The motet is given as an illustration to the article on that subject; and the accompanying example shows the relation between the themes of the Mass and those of the motet.

2. **Instrumental Masses in the Neapolitan Style.**—The Neapolitan composers who created classical forms for lyric and instrumental art-forms (see MUSIC, sec. 5) created a style of Church music best known (but not always best represented) in the Masses of Mozart and Haydn. By this time the resources of music were such that a really expressive setting of the *Gloria* and *Credo* would overload the scheme. Only a very small proportion of Mozart's and Haydn's Mass music may be said to represent ideas of religious music at all, though Haydn defended himself by saying that the thought of God always made him feel irrepressibly cheerful, and he hoped God would not be angry with him for worshipping Him accordingly. The best (and least operatic) features of such unabashed music are those which develop the polyphonic aspect of the Neapolitan style. Thus Mozart's most perfect example is his early terse Mass in F, written at the age of 17, and scored for four-part chorus and solo voices accompanied by the organ and two violins mostly in independent real parts. This scheme with the addition of a pair of trumpets and drums, and occasionally oboes, forms the normal orchestra of 18th century Masses. Trombones often played with the three lower voices.

3. **Symphonic Masses.**—The enormous dramatic development in the symphonic music of Beethoven made the problem of the Mass with orchestral accompaniment liturgically insoluble. Yet Beethoven's second Mass (in D, op. 123) is not only the most dramatic ever penned, but is, perhaps, the last classical Mass that is thoughtfully based upon the liturgy. It was intended for the installation of the archduke Rudolph as archbishop of Olmutz; and, though not ready until two years after that occasion, it shows much thought for the meaning of a church service, unique in its occasion and therefore exceptionally long. Immense as was Beethoven's dramatic force, it was equalled by his power of

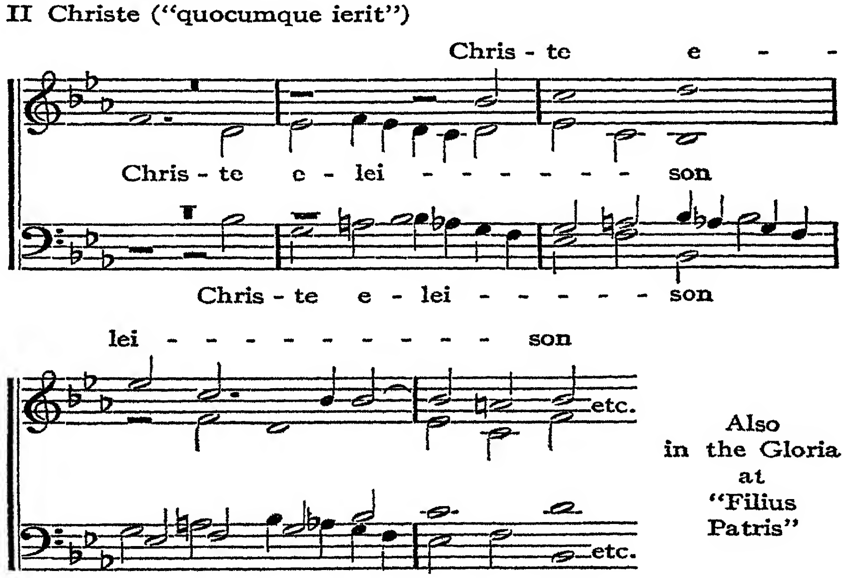
sublime repose; and he was accordingly able once more to put the supreme moment of the music where the service requires it to be, viz., in the *Sanctus* and *Benedictus*. In the *Agnus Dei* he writes as one who has lived in a beleaguered city. Beethoven read the final prayer of the Mass as a "prayer for inward and outward peace," and, giving it that title, organized it on the basis of a contrast between terrible martial sounds and the triumph of peaceful themes.

Schubert's Masses show rather the influence of Beethoven's not very impressive first Mass, which they easily surpass in interest, though Schubert did not take pains, like Beethoven, to get his Latin text correct. The last two are later than Beethoven's Mass in D and contain many splendid passages, besides a dramatic (though not realistic) treatment of the *Agnus Dei.*

Weber's two Masses (G and E flat) are excellent works; the larger one (in E flat) achieving an ecclesiastical style as good as Cherubini's and much less dry. Otherwise the five Masses and two Requiems of Cherubini (*q.v.*) are the most important works of their period. Those that were written within Beethoven's lifetime made him regard Cherubini as the greatest master of the day. Since Schubert's time the Viennese tradition of Mass music has been worthily represented by Bruckner (*q.v.*). Dame Ethel Smyth's Mass (1890) owes nothing to tradition, but is undoubtedly a work inspired by its text.

4. **Lutheran Masses.**—Music with Latin words is not excluded from the Lutheran Church, and the *Kyrie* and *Gloria* are frequently sung in succession and entitled a Mass. Thus the four Short Masses of Bach are called short, not because they are on a small scale (which they are not), but because they consist only of the *Kyrie* and *Gloria.* Bach treats each clause of his text as

II Christe ("quocumque ierit")



Also in the Gloria at "Filius Patris"

a separate movement, alternating choruses with groups of arias; a method independently adopted by Mozart in a few early works and in the great unfinished Mass in C minor. This method, carried throughout an entire Mass, will fit into no liturgy; and Bach's B minor Mass must be regarded as an oratorio.

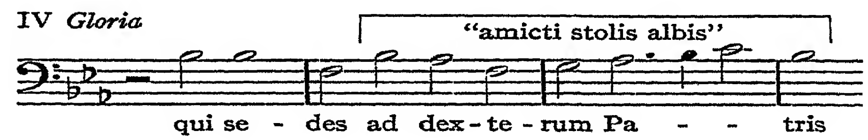
The most interesting case is the setting of the words: "Et exspecto resurrectionem mortuorum et vitam venturi saeculi.—Amen." The greatest difficulty in any elaborate instrumental setting of the *Credo* is the inevitable anti-climax after the *Resurrexit.* Bach contrives to give this anti-climax a definite artistic value; all the more from the fact that his *Crucifixus* and *Resurrexit,* and the contrast between them, show him at the height of his power. To the end of his *Resurrexit* chorus he appends an orchestral *ritornello,* formally summing up the material of the chorus and thereby destroying all sense of finality as a member of a large group. After this the aria "Et in spiritum sanctum," in which five dogmatic clauses are enshrined like relics in a casket, furnishes a beautiful decorative design, as a point of repose. Then comes a voluminous ecclesiastical fugue, "Confiteor unum baptisma," leading, as through the door and world-wide spaces of the Catholic Church, to that veil which is not all darkness to the eye of faith. At the words "Et exspecto resurrectionem mortuorum" the music plunges suddenly into sublime and mys-

III Kyrie ("sequuntur Agnum")

Also in the Gloria at "tu solus sanctus" and in Agnus Dei at "miserere nobis."

terious modulations in a slow tempo, until it breaks out as suddenly into a vivace e allegro of broad but terse design, which comes to its climax rapidly and ends as abruptly as possible, the last chord being carefully written as a short note without a pause. This gives finality to the whole *Credo* and contrasts admirably with the coldly formal instrumental end of the *Resurrexit* three movements further back. Now, such subtleties might be thought beyond the power of conscious planning. But Bach's vivace e allegro is an arrangement of the second chorus of a church cantata, *Gott man lobet dich in der Stille;* and in the cantata the

IV *Gloria*

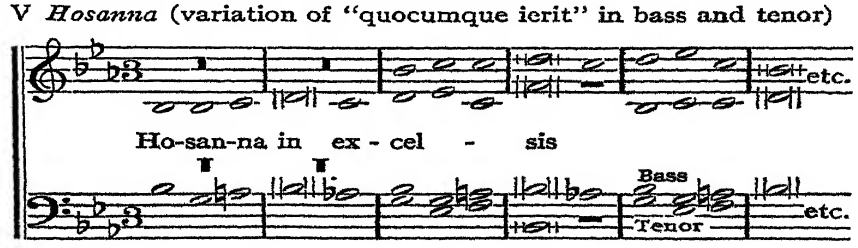


chorus has introductory and final symphonies and a middle section with a *da capo!*

Until fairly late in the 19th century the Sing-Akademie of Berlin (and perhaps other choral societies in Germany) maintained a laudable tradition according to which its director glorified his office in a Lutheran Mass (*Kyrie* and *Gloria*) for 16-part unaccompanied chorus. Some of these works (notably that of C. F. C. Fasch) are very fine.

5. **The Requiem.**—The *Missa pro defunctis* or Requiem Mass has tended to produce special musical forms for each individual

V *Hosanna* (variation of "quocumque ierit" in bass and tenor)



case. The text of the *Dies Irae* imperatively demands either a dramatic elaboration or none at all. Even in the 16th century it could not possibly be set to continuous music on the lines of the *Gloria* and *Credo.* Fortunately, its Gregorian *canto fermo* is very beautiful and formal; and the 16th century masters either, like Palestrina, left it to be sung as plain-chant, or set it in versicles (like their settings of the *Magnificat* and other canticles) for two groups of voices alternatively, or for the choir in alternation with the plain chant of the priests.

A *Dies Irae* with orchestral accompaniment cannot avoid illus-

trating its tremendous text regardless of ecclesiastical style. But it is a sour view that denies the title of great Church music to the sublime unfinished *Requiem* of Mozart (the Italian antecedents of which would be an interesting subject) and the two important works by Cherubini. These latter, however, tend to be funereal rather than uplifting.

Of later settings, Schumann's belongs to the days of his failing power; Henschel's is a work of great sincerity and reticent beauty; while the three other outstanding masterpieces renounce all ecclesiastical style. Berlioz seizes his opportunity like a musical E. A. Poe; Dvořák is eclectic; and Verdi towers above both in flaming sincerity, no more able to repress his theatrical idioms than Haydn could repress his cheerfulness.

Brahms's *Deutsches requiem* has nothing to do with the Mass for the dead, being simply a large choral work on a text compiled from the Bible by the composer. (D. F. T.; X.)

MASSA, a town of Tuscany, Italy, the joint capital with Carrara of the province of Massa and Carrara, and sharing with it the episcopal see, 20 m. S.E. of Spezia by rail, 246 ft. above sea-level. Pop. (1931) 17,561 (town); 39,841 (commune). The Palazzo Ducale (now the prefecture) was erected in the 16th century by the Cybo-Malaspina family, who also built the old castle above the town. Marble from the hills round the town is shipped at the Marina di Massa.

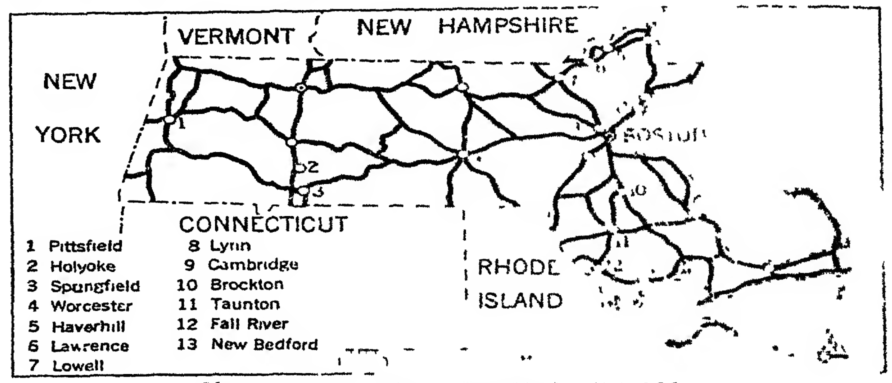
MASSACHUSET, the Algonkin tribe formerly about Boston, from whom the bay and state of Massachusetts were named. They may once have numbered 3,000, but were reduced by pestilence before the colonial settlement began, continued to decrease, although they avoided conflict with the whites, became Christians and soon lost their tribal identity.

MASSACHUSETTS, popularly known as the "Bay State," is one of the New England group of the United States of America. The name Massachusetts was derived from that of an Indian tribe. It was one of the earliest English colonies in America and one of the original 13 States forming the American Union.

Until 1819 it included what is now the State of Maine but as since constituted it is bounded on the north by Vermont and New Hampshire, on the east by the Atlantic ocean, on the south by the ocean, Rhode Island and Connecticut, and on the west by New York. Owing to its peculiar form, these boundaries are only approximate in the east. Its main portion forms a parallelogram about 130m. from east to west and 46m. from north to south, its straight southern boundary being almost coincident with the parallel of 42 N. In the east, the State spreads out, extending considerably south and somewhat north of the lines of the parallelogram, the counties of Plymouth and Barnstable forming the peculiar "pot-hook" of Cape Cod. The State extends approximately from 69° 57′ to 73° 30′ W. Boston, the capital and principal city, is in about the same latitude as Rome. The total area is 8,266sq. m., of which about 227 are water.

Physical Features.—These can be understood in their full significance only by a slight reference to those of New England as a whole. The Appalachian mountain barrier which extends from south-west to north-east parallel to most of the eastern coast-line of the United States continues through western New England in the Berkshire hills and the Green and White mountains. From the base of these ranges a gently sloping upland descends south and eastward to Long Island sound and the Atlantic ocean. The only large river, navigable for any considerable portion, is the Connecticut, which flows southward from the Green mountains of Vermont to the Sound. As Massachusetts in form is a long narrow strip extending westward from the ocean, it runs at right angles, so to speak, to these principal New England features of mountains and river. Its eastern two-thirds is mostly made up of the sloping upland. West of that the State is divided by the Connecticut valley, the best portion and maritime outlet of which is in Connecticut, and west of that again lie the mountainous western counties.

There are several small ranges, each with local names, in the Berkshires. The more eastern is that known as the Hoosac hills which have an elevation of only 1,200 to 1,600ft. and divide the valley of the Connecticut river from that of the smaller but more picturesque Housatonic. Bordering the lowlands of the Connecticut a few well-known hills rise to a marked height above the general level, such as Mt. Tom (1,214ft.), Mt. Holyoke (954ft.) and Mt. Toby (1,275ft.). West of this, in what is known locally as more particularly the Berkshire region we find such peaks as Mt. Williams (3,040ft.) and Greylock (3,535ft.). From the Connecticut valley eastward the elevations steadily decrease to the coast and the extreme south-eastern portion is low-lying and sandy.



MAP OF MAIN ROADS IN MASSACHUSETTS

There are a few exceptions, such as Mt. Lincoln ([illegible]), Mt. Wachusett (2,108ft.) and the Blue hills. These, like those mentioned in the western section, appear to be residual peaks of an original mountain range which covered the entire State in the geological era before the whole had been levelled to the plain which was then, by the secondary process already noted, carved into its present features. The existence of this original mountain range is also indicated by the structure and extremely contorted [illegible] of the gneiss and crystalline schist on the uplands. On the other hand, the valley of the now much shrunken Connecticut river is composed mainly of shale and soft sandstone. The evidences of the glacial period occur everywhere, the entire State having been covered by the ice-sheet, with resultant [illegible] as far as the Cape Cod peninsula, where we find traces of the terminal moraine.

The eastern part of the State can best be described [illegible] in terms of the junction of sea and land, though there is one small river, the Merrimack, which is important [illegible] its very short navigable portion [illegible] for the [illegible] power it provides by its fall. The coast line, owing to [illegible], extends for about 250m., with a number of good harbours. The enormous water area included between the two points of Cape Ann and Cape Cod is known as Massachusetts bay, [illegible] Cape Cod bay for its southern portion. Among the harbours, all of which are excellent, may be mentioned those of Salem, Gloucester, Marblehead, Boston and Provincetown on the [illegible] and Buzzard's Bay, a popular yachting resort, on the south. The northern part of the eastern shore is somewhat rocky and picturesque, whereas the long "pot-hook" formation of the Cape Cod peninsula (Barnstable county), is low and sandy. Almost the entire coast is lined with summer resorts, those to the north of Boston giving to that section the nickname of the [illegible] owing to the great wealth concentrated there, while Cape Cod is as yet somewhat simpler, attracting the more conservative old families and the intellectual and aesthetic [illegible] a somewhat noted artistic and literary colony at Provincetown. At Woods Hole on Buzzard's bay is the U.S. Bureau of Fisheries station with a marine biological laboratory. Leaving the mainland there are several islands to the south, two of them, Martha's Vineyard and Nantucket, being of considerable size and importance. Martha's Vineyard, a little the larger (about [illegible] by 20m.), has a good harbour which, aside from summer yachting, is resorted to by storm-bound vessels avoiding the dangerous shoals which lie to the south-east of the State.

The physical features thus briefly described, have had a marked effect upon the history of Massachusetts at every period. In the colonial days, when waterways provided the only means of travel, the absence of any large river leading to the interior retarded development of the sections lying back of the coast prevented the

development of the fur trade and led the people to look to fisheries and commerce for their livelihood, an influence which was strengthened by the rather poor soil of most of the State. This latter fact also determined that Massachusetts farms should be mostly small, and prevented, as did the climate, the growth of large estates and a slave economy as in the South. The broken character of the eastern upland has had a marked effect also, the richer valleys having afforded moderate ease and comfort, which resulted in conservative politics, whereas the "hill towns" were poorer, radical in politics, and largely abandoned when a changed economic situation and western expansion opened new opportunities for their dwellers. The fact that the Connecticut river merely ran through the State, flowing thence into another, led the inhabitants of this richest of all sections to ally themselves rather with their neighbours to the south in Connecticut than with their own fellow-citizens to the east. To the west of this, the mountainous and somewhat rugged land gave special character to its inhabitants who have always shown themselves more democratic and radical than those in the mercantile towns of the seaboard. As a whole, the mountain barrier to the west long tended to isolate New England from the rest of the country, to preserve the New England type, and to produce a certain provinciality of outlook in which Massachusetts shared. Although railways overcame this isolation to some extent, the great traffic from the west goes to New York rather than Boston, and both commerce and manufactures are declining relatively to those in competing States. On the other hand, the beautiful scenery and charm of summer life are attracting more and more people and the motor car is bringing unexpected prosperity to villages which two decades ago seemed doomed.

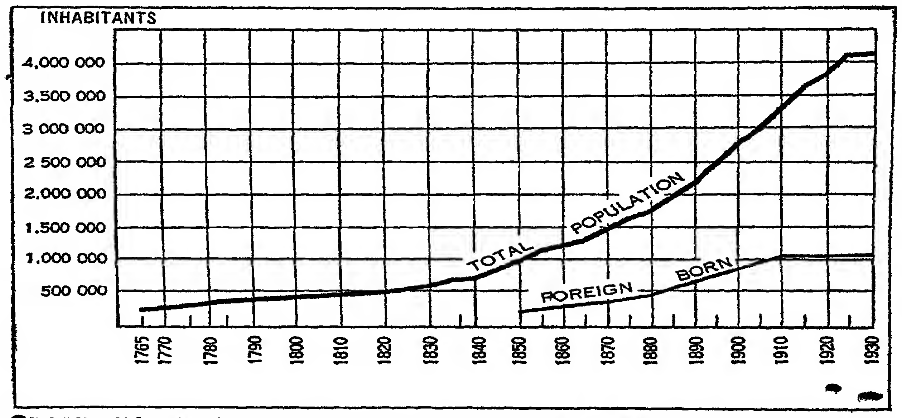
Climate.—The winters are long and extremely severe, passing through a very short spring abruptly into summer, a winter which Henry Adams said is "always the effort to live" and a summer which is "tropical licence." The autumn is apt to be fine, and the air, especially in the Berkshire hills, dry, cool and bracing. Although varying in different parts of the State, the annual extremes of temperature are about 20° below zero to 100° or more above, with a mean average at Boston of 48 degrees. The mean summer average throughout the State is 70° and the winter (at Williamstown) 23 degrees. The lowest recorded temperature is —28° in the Connecticut valley. The annual precipitation varies from 38 to 48in., evenly distributed through the year. There is much fog along the coast. Nantucket and portions of Cape Cod are located in a somewhat different climatic belt in which the temperatures are milder with a larger proportion of sunshine in the year.

Fauna and Flora.—There is little that is distinctive in either as differentiated from New England as a whole. The State is a meeting place, however, for many southern and northern species of which it forms respectively, the northern and southern limits. It is, for example, the northern limit of such trees as the holly and Tupelo, the latter occasionally found in southern New Hampshire also. There is a small colony of prickly pear cactus in Nantucket. It is also the northern limit of many insects, notably the 17-year locust. Among the birds likewise limited are the seaside sparrow, blue-winged warbler, prairie warbler and quail. On Martha's Vineyard there is a rapidly dwindling colony of the almost extinct heath hen. The most remarkable feature of the State from the standpoint of its fauna and flora is the influence of Cape Cod which stretches out to sea and deflects the current of the Gulf stream. To the south of the Cape are found many southern fishes and other marine creatures, including the Portuguese man-of-war. In the cold waters on the north side of the Cape the fish and invertebrates are entirely different so that it is said that no other barrier makes so sharp a dividing line in ocean faunas.

Population.—On April 1, 1930, the population was 4,249,614, or 528·6 persons per sq.m., the density having steadily increased from 278·5 in 1890. It is the third most densely populated State in the Union. In 1930 90·2% of the population lived in urban communities numbering over 2,500 and 66·2% in places of 25,000 and above, 2,307,897 being in what is known as the Metropolitan area of Boston. In the year 1930 populations of the ten largest cities were respectively: Boston (proper), 781,188; Worcester, 195,311; Springfield, 149,900; Fall River, 115,274; Cambridge, 113,643; New Bedford, 112,597; Somerville, 103,908; Lynn, 102,320; Lowell, 100,234; Lawrence, 85,068.

The increase in population between 1920 and 1930 was irregularly distributed, but every county showed an increase, the most notable being Middlesex where the increase was from 778,352 to 934,924, Norfolk from 219,081 to 299,426, and Suffolk from 835,522 to 879,536.

In 1930 98·7% of the population was white, 1·2% negro, and ·1% Indian and all others. Of the white population 33·6% was of native-born parentage, 28·3% of foreign parentage, 11·9% of mixed, and 24·8% foreign-born. Owing to their tendency to congregate in cities, the largest percentage of foreign-born is in the counties of Suffolk, Bristol, Essex, Norfolk, Middlesex, Hampden, and Worcester.



GRAPH SHOWING THE GROWTH OF POPULATION IN MASSACHUSETTS FROM 1765 TO 1930, WITH THE NUMBER OF FOREIGN BORN

Of the foreign-born population (1930) 299,040 were from Canada and Newfoundland (115,241 of them French Canadians), 138,366 from the Irish Free state, 20,378 from Northern Ireland, 126,103 from Italy, 78,418 from England, 71,442 from Poland, 67,684 from Russia, 36,810 from Sweden, 32,724 from Scotland, 25,219 from Lithuania, 24,840 from Portugal, and 20,538 from Germany.

The preponderance of females over males is greater than in any other State in the Union, there being (1930) 2,071,672 males and 2,177,942 females. At the age of 64, 80·2% of the population are or have been married; 1,814,422 persons over 10 years of age are engaged in gainful occupations (1,284,454 male and 529,968 female); and of these almost half, or 837,446, are in manufacturing as against only 63,942 in agriculture, forestry, and fishing.

Until nearly the end of the 18th century the population was unusually homogeneous. In 1794 some apprehension was expressed over the numbers of Irish arriving but the great wave of Irish immigration did not occur until the decade 1830–40. The great increase in the Italian population has mainly taken place since 1885. By 1850 the native population had largely been driven out of manufacturing by the influx of foreigners who underbid them on wages. Owing to immigration the population has become overwhelmingly Roman Catholic.

Government.—The first government, other than that of the Plymouth settlement, was based upon the charter of 1629 which was intended to be merely the charter for a commercial company, but which was twisted by the colonists into a political constitution The system of "towns" created became the most characteristic feature of the New England system. The word meant a "township," an area of considerable extent which might include several settlements, villages, etc. Each township had the right of sending deputies to represent it in the General court, as the legislature was styled. The affairs of the towns, including election of officers and representatives, were conducted in town meetings at which all citizens had the right to speak although the franchise was for long limited by religious requirements. The town meeting was a political school of prime importance and although the system has less significance now it has been abandoned slowly and with reluctance even in the larger places, Boston, for example,

primacy and is still the leading market in America and one of the principal markets of the world. Wool receipts at this centre have fluctuated considerably during the past quarter century without showing any consistent trend either upward or downward. In 1934, a comparatively low year, they totalled 200,800,000 pounds (183,581,000 pounds domestic and 17,219,000 pounds imported). The total for 1935 was 272,970,000 pounds, of which 226,715,000 pounds were domestic and 46,255,000 pounds were foreign.

The following table gives the total value of all commodities in foreign trade passing through the ports of the State.

	General Imports	Exports
1901	$ 61,452,000	$143,708,000
1925	321,567,000	47,494,000
1930	176,199,000	33,633,000
1932	72,561,000	15,731,000
1935	110,335,000 (for consumption only)	24,575,000

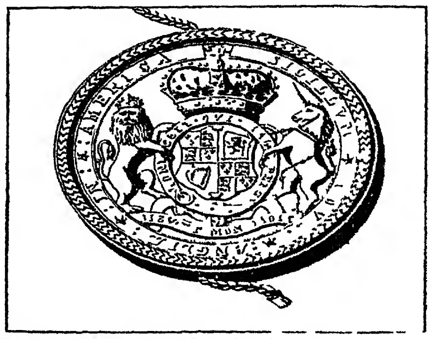
The total sea-borne commerce of the several ports of Massachusetts, in short tons, for 1935 was: Beverly, 624,125; Boston, 16,384,958; Fall River, 1,887,130; Lynn, 384,551; New Bedford, 642,030; Salem, 411,817.

Transportation.—The State in 1934 was served by 1,992 miles of steam railway as compared with 2,131 miles in 1915. The electric railway mileage also decreased from 3,056 in 1915 to 1,305 in 1932. The road mileage in the State highway system on December 31, 1934 was 1,833, all of which was surfaced. There were 785,090 motor vehicles registered in 1935.

HISTORY

Early Settlements.—It is uncertain when Massachusetts was first visited by Europeans. In spite of conjecture there is no proof of anyone having been there before Bartholomew Gosnold in 1602, who visited Massachusetts bay and named Cape Cod. Two years later Champlain explored the coast and in 1614 John Smith also did so, naming many of the points along it. After that, visits became more frequent but it was not until many years after other settlements had been made in America that a permanent colony was planted there. This was at Plymouth, in 1620. Certain religious enthusiasts had fled from England to Holland some years before and from there decided to migrate to the New World. After considering Guiana and other places, they determined to try the territory owned by the Virginia company, and financial assistance was received from colonizing-speculators in London. The London promoters provided the money and when the Mayflower sailed, of its 102 passengers only 35 came from the Leyden religious group, and 67 from London. The leaders before landing drew up the famous "Mayflower Compact" to serve as the basis of government. There was no intention of making a new departure in the direction of a democratic constitution, and the short document was merely a modification of the customary form of church covenant to meet the temporary crisis in an unfamiliar situation. As, owing to mere stress of weather or some other unknown cause, the colonists landed in Massachusetts instead of Virginia, they had no other government than this formed by themselves, and the pure democracy thus inaugurated and later modified, was accidental. It became, however, the precursor of innumerable other written covenants in New England forming the basis of town and church government there. The troubles of the first winter were severe and half the colony died, including Governor Carver, whose place was taken by William Bradford. Fortunately for the colonists the Indian tribes had been decimated by illness a few years earlier and the settlement had little trouble on that score. The contract with the London promoters had called for ownership of property in common, but this was soon modified by stress of circumstances in favour of individual property. The colony, although it managed to survive its initial difficulties, was never financially successful and eventually all connection with the English company was terminated. After the adjustment of accounts with its financial sponsors, the colony succeeded in getting grants defining its territorial boundaries, and gradually the village of Plymouth threw off other little settlements, such as Scituate (1636) and Duxbury (1637), but was finally absorbed into the larger and more powerful colony of Massachusetts Bay in 1691.

Soon after the Plymouth settlement was made others were established along the coast, mostly by individuals, a number of whom from 1625 onward settled around Boston Harbor A small fishing company tried to establish a foothold and business on Cape Ann which was the forerunner of a much more important colonizing movement than any yet made in North America. In England it was a time of much change and unrest, quite as much political and economical as religious. The Puritans were drawn to a great extent from country gentlemen and middle-class business men, all of whom were feeling the stress of the times severely. There was a great migration of the discontented to the New World, a migration by no means confined to New England. Between 1620 and 1642, for example, 18,600 persons went to Barbadoes as compared with only 14 000 to Massachusetts, and 18,000 to other West India Islands as compared with less than 4,000 to the rest of New England. The Massachusetts settlement was thus merely an episode in a much broader movement Certain Puritans in England became interested in an attempt to revive the defunct fishing company at Cape Ann, and in 1628 a patent was received from the Council for New England and a number of settlers were sent out under John Endicott as governor. Meanwhile the number in England interested in a Massachusetts venture had increased, and in 1629 a rather strong group, including John Winthrop, obtained a charter as "The Governor and Company of the Massachusetts Bay in New England." The grant was similar to that of the Virginia Company in 1609, the patentees being joint proprietors, with rights of ownership and government The intention of the Crown was evidently to create merely a commercial company with what in modern parlance, we would call stockholders, officers and directors, but by a shrewd and legally questionable move, the patentees decided to transfer the entire management and the charter itself to Massachusetts thus paving the way for not only making the management local but also for the unwarranted assumption, pregnant with most important consequences, that the charter for a commercial company was in reality a political constitution for a new government with only indefinable dependence upon the imperial one at home



FROM "PROCEEDINGS," MASSACHUSETTS HISTORICAL SOCIETY

THE GREAT SEAL OF MASSACHUSETTS DURING THE REIGN OF GEORGE II.

The religious motive was but one among others inducing even the leaders to emigrate to America It was undoubtedly important, but even it looked merely to the establishment of a community in which the emigrants would be free to worship as they themselves wished, not to establish in any way a refuge for those who might wish to worship differently Indeed throughout the whole colonial period, the leaders of the colony fought religious liberty with every weapon in their power. The economic motives were also strong (as Winthrop clearly indicated in writing in his own case), the sudden increase in the cost of living in England with consequent unsettlement of established habits and social position, being a leading factor. In the summer of 1630 a fleet of ships carried over nearly 1,000 emigrants, including Winthrop as governor and Thomas Dudley as deputy governor to Massachusetts bay, where they settled the towns of Boston, Charlestown, Dorchester, Medford, Watertown, Roxbury and Lynn. Such leaders as Winthrop, Dudley, Endicott and the Rev John Cotton were strongly opposed to democracy, were zealous to prevent any independence in religious views, and had no trust in the people at large. Opposition showed itself now and then in the case of individuals, the General court or even a town (as Watertown). The first of the more noted cases was that of Roger Williams who was banished from the colony and settled in Rhode Island (1636). Almost simultaneously occurred the Antinomian Controversy in which Ann Hutchinson and Harry Vane the younger were the protagonists, and which ended in the banish-

ment of Mrs. Hutchinson and the return of Vane to England. There was much criticism in England, even among the friends of the colony, of the policy of repression adopted by the leaders, lay and clerical, but they pursued their course until halted by royal authority a generation later. The harshness of rule, narrow-mindedness and self-satisfaction which became characteristic of the Massachusetts colony cannot be ascribed wholly to Puritanism. As has been said, it was a period of great Puritan emigration and all the colonies both on the American mainland and in the West Indies were strongly Puritan in tone at first. In the South and on the islands, differing climatic and other conditions induced modifications in cultural life and thought, but even in New England both Rhode Island and Connecticut were far more liberal than Massachusetts.

Extension of settlements brought on troubles with the Indians and in 1637 there occurred the war with the Pequots, in which that race was practically annihilated. In the same year a synod of the clergy was held at Boston which listed 82 blasphemous, erroneous or unsafe opinions held in the colony. In 1643 a loose confederation of the four colonies of Massachusetts, Connecticut, Plymouth and New Haven, was effected under the title of the United Colonies of New England. It performed some useful work but its policies were largely dominated by Massachusetts and it gradually lost influence.

In 1644 laws were passed against the Baptists and several of them were cruelly dealt with. The Quakers also were persecuted, more particularly from 1656 to 1662, four being put to death and many others whipped, imprisoned, branded or banished. Finally, owing partly to a revulsion of public feeling and largely to action by the English Crown, a stop was put to the worst forms of persecution. During the Civil War and Cromwellian period in England, the colonies had for the most part been left to go their own way and Massachusetts had arrogated to herself an almost complete independence of the home government. It was obvious according to the ideas of the time that if the colony were to remain part of the empire a closer dependence would be essential, and after the Restoration it was decided to send out a Royal Commission to investigate conditions. In 1665 the Commission visited New England, and the following year the king sent a circular letter to all the colonies, expressing dissatisfaction with Massachusetts only. There was, indeed, a considerable and respectable party in the colony itself which was opposed to the extreme pretensions of the local government. That government, however, trusting to distance and the preoccupation of England with the European war, pursued its course.

In 1675 there occurred a second and much more serious Indian war, known as King Philip's War, due to the grasping land policy of the colonies and the desperation of the savages at seeing themselves more and more hemmed in by the whites. It was an inevitable conflict and although the whites were victorious they suffered severely. It was said that one man in every 16 of military age was killed and it was long before the frontier recovered. Meanwhile the case of Massachusetts was again taken up by the English government. The colony adopted the method of evasion and delay in meeting charges and complying with orders. This policy resulted in the annulment of the charter in 1684, in leaving the colony defenceless against the king, and with few or no friends in England to defend the course it had taken. In some respects, such as the end of the exclusion of non-church members from the franchise, the cause of liberty gained by the change. In 1686 a royal government was inaugurated by the arrival of Joseph Dudley, a native Massachusetts man, as president of a provisional government until a new one could be devised. He was soon supplanted by Sir Edmund Andros, whose government extended over all New England and New York. Although he was by no means the "tyrant" whom the earlier patriotic historians painted, he was lacking in tact and in the qualities of wise statesmanship, and his situation was an extremely difficult one. When word came that the Stuart dynasty had been overthrown in England in favour of William of Orange, a mild revolution occurred in Boston, and Andros and most of his government were imprisoned. Finally a new charter was procured for Massachusetts, 1691, to whose territory it added the province of Maine and the former colony of Plymouth. Although the new charter provided for a royal governor and in other ways greatly diminished the power of the old theocratic party it was a more reasonable governmental instrument than the anomalous commercial charter which the colony had for so long tried to twist into a political constitution. The first royal governor was a New England man, Sir William Phips, who had led an unsuccessful attack on Quebec in 1690. Massachusetts had carried out an easy raid upon Acadia which had inspired hopes of a larger conquest of French territory, with the sole result of almost bankrupting the colony by a debt of £200,000. The last decade of the 17th century was also marked by the witchcraft delusion, mainly in Salem village, during 1691–92. In all about 32 persons were executed, one by the horrible mediaeval penalty of being pressed to death under heavy weights. After the end of that delusion, the life of Massachusetts takes on a more modern tinge. Connecticut had shown the way to civil and Rhode Island to religious liberty. If the far more powerful colony of Massachusetts cannot lay claim to have been a leader in either of these directions, its founders had established the strongest colony in North America, had made creditable beginnings in public education, had developed the system of town government, and laid the foundation for the Congregational Church. Although the results of the intellectual repression of its first century were long to be felt, with the opening of the new century the colony swung more and more into the growing liberalism of thought of the 18th century.

It also shared more in the larger life of the empire. Several times, notably in the unfortunate expeditions against Jamaica (1702), against Canada (1709–11) and Cartagena (1740), Massachusetts troops played an honourable part, and to that colony must be given the main credit for the capture of Louisburg from the French in 1745. In the French and Indian war her soldiers also took part in the expedition against Oswego, took the chief part in the capture of Acadia, and also shared in the Crown Point and second Louisburg attacks. Meanwhile, the colony had been making rapid strides in wealth and was becoming markedly self-conscious politically. There had been serious trouble with the currency earlier in the century, owing to the colonists' insistence, perhaps necessary, upon the use of too large amounts of paper money, in which it was opposed by the English government. This trouble culminated in a crisis, including rioting, under Governor Belcher in 1740 but the repayment to the colony by England of about £183,000 in sterling to cover its expenses in the capture of Louisburg (1745) enabled it to retire about £2,000,000 of its depreciated bills and establish itself on a firm money basis, a fact of great importance in its subsequent commercial development. Fortunes were accumulating, business operations were growing much larger in scale, Harvard had become liberal in thought, and Connecticut, not Massachusetts, had now become the last stand of the old religious ideas.

During the war there had been much smuggling and trading with the enemy, and the British government became more stringent in trying to enforce trade regulations. In 1756 it introduced a system of general search warrants, such as Massachusetts itself had had in force for eight years. Merchants who saw their profits endangered protested, and in 1761 James Otis made his famous and impassioned attack in court upon these Writs of Assistance, the strict legality of which was hardly open to question. Following the peace of 1763 and the need for readjusting the cost of maintaining and defending the empire, came the fatal attempts to solve the problem. In 1765 Massachusetts was prominent among the colonies which resisted the Stamp Act. Samuel Adams of Boston, one of the ablest agitators and propagandists whom any country has produced, set himself to keep alive the flames of discontent, having made up his mind that the colonies should be wholly independent of England. In his skilful manipulation of public opinion and emotion, and in his organization of the Committees of Correspondence, he probably did more than any other man to arouse the opposition of certain elements against England and to prevent the possibility of any reconciliation. In 1768 royal troops were stationed in Boston and on March 5, 1770, a clash

occurred between them and some citizens of whom five were killed. The soldiers had been constantly subjected to taunts and abuse and on the whole had behaved well. In this incident a small mob, led by a half-breed negro, had been the aggressors. Officers and men at once surrendered to the civil authorities and upon trial by the local court were acquitted, except two who received slight penalties for technical homicide. Samuel Adams and his party made the most possible of the "atrocity" and dubbed it "the Boston massacre." In 1773 occurred the "Boston tea party" in which a band of citizens disguised as Indians boarded the ships carrying the tea and threw it overboard. In retaliation for this wanton destruction of private property (not considered necessary in any other colony), Parliament passed the Boston Port bill, closing the port to commerce. The increasing agitation and violence of the mobs during this decade presaged more serious armed conflict. Gen. Gage was made governor and in April 1775 sent an armed force to Lexington and Concord to destroy military stores gathered at those places by the Opposition. The force was attacked and completely routed by the country people, and Gage was practically besieged in Boston. In an effort to release himself the battle of Bunker Hill was fought June 17, resulting in a costly but psychologically complete victory for the Americans. The British loss was exceedingly heavy. In July Washington arrived at Cambridge to take command of all the troops, and soon after the scene of war shifted from Massachusetts and no important military action occurred within it for the rest of the struggle. During the whole of it Massachusetts contributed more liberally than any other colony in men and money though military leadership, except for Generals Henry Knox and Benjamin Lincoln, passed to other hands.

Two years of prosperity following the signing of peace in 1783 soon gave place to serious financial difficulty, particularly among the poor and heavily taxed farming class. Violence occurred in most counties and became especially serious in the western ones. Owing largely to the failure of the legislature either to suppress the insurrection or to redress grievances, the revolt gained headway. Many ex-Revolutionary soldiers and officers took part in it, among others Capt. Daniel Shays, and owing to his leadership the movement became known as Shays's rebellion. It was finally put down by aid of heavy forces under Gen. Lincoln. The incident was important as frightening the moneyed classes into accepting more readily the new Federal constitution. This was ratified by only a very small majority in Massachusetts which was considered a "pivotal state." After its adoption the State became strongly Federalist in politics. A group of its leading politicians, known as the "Essex Junto" and including such men as Fisher Ames, George Cabot, Timothy Pickering, John Lowell and others (all opponents of democracy and strongly reactionary) long dominated the politics of the State. They were utterly out of sympathy with the principles of the party in national power after 1800 and with the policy of war against England in 1812. On the whole, the part played by the State in that war was inglorious. As a commercial community it had suffered heavily from the embargo measures preceding it, but it is difficult to justify the extreme sectionalism and anti-nationalism displayed when the nation was actually at war. Although New England held most of the specie of the country it refused, in the main, to subscribe to the war loans and Boston took only $75,000 of that of 1813 as compared with $7,000,000 subscribed in Pennsylvania. Although great numbers of its citizens supported the Government, the policy of the State as a whole was distinctly obstructionist and disloyal. Rumours of secession, which had been heard at intervals from 1800, seemed to find confirmation with the convening of the Hartford Convention, mainly dominated by Massachusetts, in 1814. The more sober element prevailed, however, and the convention adjourned doing but little harm except to the reputations of those who had attended. The State also opposed the Mexican War as it had the policy leading to it. The period 1830–40 witnessed great social changes, among others the rise of the factory system and the substitution to a great extent of imported foreign for native American labour. It was a period of intellectual ferment and of social experiment. Utopian communities, such as Brook Farm, were undertaken, and although they all ended in failure, they left their mark on the thought and idealism of the times. Under the lead of Wm. Lloyd Garrison and Wendell Phillips, Massachusetts was in the van of the Abolitionist movement. Such citizens as C. F. Adams and Charles Sumner took leading parts in the formation of the Free Soil Party, and when at last the Civil War came, the State entered the contest whole-heartedly, rallying to the support of the Federal Government in a spirit utterly different from that which had marked the two preceding ones. It has been stated that of the 159,165 men (including re-enlistments) whom the State sent to the war less than 7,000 were drafted. After the war the Republicans maintained a fairly continuous control until 1911. The industrialization of the State and the increasing domination of the cities by newer immigrant peoples has strengthened the Democrats, and, except for the post World War era (1916–1929), they have since dominated the State. In 1928 Massachusetts was among the few supporters of Alfred E. Smith, and in 1932 and 1936 she voted decisively for Roosevelt.

Owing to the extraordinary number of able men, the influence of Massachusetts in the intellectual life of the nation has been out of all proportion to its size and population. The roll of historians has been notable, including John Winthrop and William Bradford in the settlement period, Thomas Hutchinson in the revolutionary one and culminating with Bancroft, Sparks, Prescott, Motley, Parkman, Thayer, Henry Adams, historian and philosopher, and Rhodes by adoption. In poetry we have R. H. Dana, Bryant, Longfellow, Whittier, Lowell, Holmes and Amy Lowell; in philosophy and theology, Jonathan Edwards, Channing, Emerson, Parker and William James; in fiction, Mrs. Stowe and Hawthorne; in education, Horace Mann and Charles W. Eliot; in oratory and statesmanship, James Otis, John Adams, John Quincy Adams, Webster, Choate, Everett, Sumner, and Wendell Phillips; in social statecraft Josiah Quincy, S. G. Howe and B. F. Sanborn; and in law, Story, Parsons, Shaw, Holmes and Brandeis.

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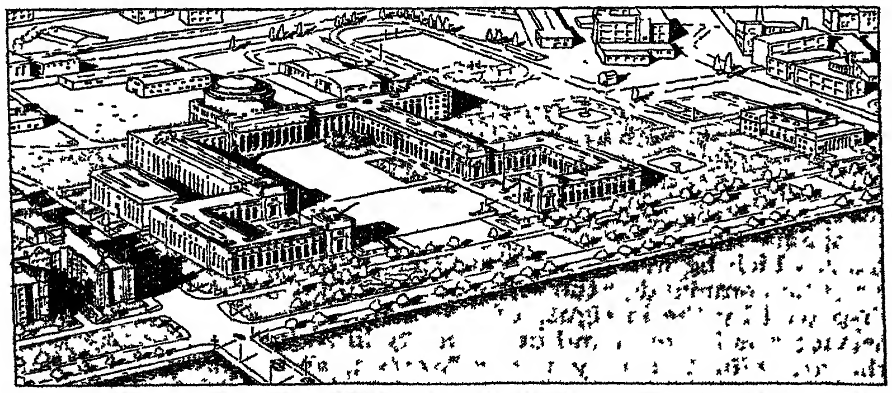
somewhat antiquated as to date but not in scholarship. J. T. Adams, *History of New England* (1927) (originally published separately with distinct titles), contains footnote references to several thousand works on New England, largely Massachusetts. J. G. Palfrey, *History of New England* (1858–90) is now out of date and belongs to the old "filio-pietistic" school. Other works are: Wm. Bradford, *History of Plymouth Plantation* (var. edits.); J. Winthrop, *History of New England, 1630–1649* (in journal form); S. E. Sewall, *Diary* (Mass. Hist. Soc.), gives an intimate picture of Boston life from 1674 to 1729; T. Hutchinson, *History of Massachusetts* (1764–1828), the publications of the Prince society, notably the *Hutchinson Papers* (1865), the *Andros Tracts* (1868–74), and the *Randolph Papers* (1898–1909); Young, *Chronicles of the Pilgrim Fathers* (1844); Young, *Chronicles of Massachusetts* (1846); C. W. Upham, *Witchcraft in Salem;* Henry Adams, *Documents relating to New England Federalism* (1877); R. P. Hallowell, *The Quaker Invasion of Massachusetts* (1887); W. B. Weeden, *Economic and Social History of New England* (1890); C. F. Adams, *Three Episodes in Massachusetts History* (1892); *ibid., Massachusetts: its Historians and its History* (1893); W. Walker, *Creeds and Platforms of Congregationalism* (1893); Ellis and Morris, *King Philip's War* (1906); F. H. Foster, *A Genetic History of the New England Theology* (1907); L. K. Mathews, *Expansion of New England* (1909); A. E. Morse, *The Federalist Party in Massachusetts* (1909); W. A. Robinson, *Jeffersonian Democracy in New England* (1916); A. M. Schlesinger, *The Colonial Merchants and the American Revolution* (1918); R. G. Usher, *The Pilgrims and their Story* (1918); A. B. Darling, *Political Changes in Mass. 1824–1848* (1925); *Diary of Cotton Mather*, and the *Winthrop Papers*, Mass. Hist. Soc. publications; the publications of the various learned societies are particularly important, notably the *Proceedings* and *Collections* of the Mass. Hist. Soc.; the *Proceedings* of the American Antiquarian Society; the *Publications* of the Col. Soc. of Mass.; and the *Register* of the N. E. Gen. and Hist. Society. Many of the town histories are excellent. The biographies and collected writings of many of the State's Leaders are important. Two recent co-operative histories are J. H. Lockwood, ed., *Western Massachusetts*, 4v. (1926) and A. B. Hart, ed, *Commonwealth History of Massachusetts*, 5v. (1927–30). (J. T. A.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE, an institution of higher education in Cambridge, Mass., was incorporated in 1861. It owes its origin to William Barton Rogers, its first president, a scientist of high rank and president of the National Academy of Science. He urged the establishment of an institute in which scientific pursuits should predominate. Owing to the outbreak of the Civil War it was not until 1865 that it was possible to make an actual beginning. The courses were especially designed to prepare men for mechanical and civil engineering and for the professions of the architect and chemist. In 1866, the institute moved into its first building on Boylston street, Boston, provided chemical laboratories and three years later physical laboratories. During 1870–76 the mining and metallurgy, mechanical engineering and me-



BY COURTESY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. PHOTOGRAPH, COPR FAIRCHILDS

AERIAL VIEW OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

chanic arts laboratories and three new courses, mining, physics and biology were established. By 1900 the number of students had increased to 1,200 and the number of the instructing staff to 153. Three more large buildings had been erected and four new courses established—in electrical, chemical and sanitary engineering and naval architecture. The magnificent new buildings of the Massachusetts Institute of Technology built some ten years later in Cambridge on the banks of the Charles river gave the institute unexcelled facilities for engineering education and research.

The institute is one of the land grant colleges. The government is vested in a corporation consisting of eight ex-officio members, including three as provided by act of the Legislature, of not less than 25 nor more than 35 life members, of 15 alumni term members and of not more than five special term members. The instructing staff in 1936 consisted of 529 members of whom 284 were of professorial grade. These professors constitute the faculty, which has immediate supervision of all matters relating to educational policies, curricula and courses of study, and to the admission and conduct of students. Exclusive of the summer school, the number of students in 1936 was 2,793; of this number 619 were pursuing graduate study. The regular course of undergraduate study leads to the degree of S.B. in the following 16 branches of engineering: aeronautical engineering, architectural engineering, building engineering and construction, business and engineering administration, chemical engineering, civil engineering, electrical engineering, electro-chemical engineering, general engineering, marine transportation, mechanical engineering, metallurgy, mining engineering, naval architecture and marine engineering, public health engineering, and sanitary engineering; to an S. B in the following sciences: biology, biology and public health, chemistry, general science, geology, mathematics and physics; and to a bachelor of architecture and to a bachelor of architecture in city planning. Opportunities are afforded for advanced degrees of master of science, master of architecture, master of city planning, doctor of philosophy, doctor of science, and doctor of public health. (S. W. S.)

MASSACRE, a wholesale indiscriminate killing of persons. The meaning and the old form *macecle* seem to point to a corruption of the Lat. *macellum*, butcher's shop or shambles, though it may be derived from Old Low Ger. *matsken*, to cut in pieces.

MASS ACTION, LAW OF: *see* CHEMICAL ACTION.

MASSAGE, a method of treating stiffness or other physical conditions by manipulating the muscles and joints, practised from time immemorial in all parts of the world and employed extensively for medical purposes at the present time.

Massage, as now practised, includes several processes, some passive, others active. The former are carried out by an operator, and consist of rubbing and kneading the skin and deeper tissues with the hands and exercising the joints by bending the patient's limbs. The active movements consist of a special form of gymnastics, designed to exercise particular muscles or groups of muscles. In "Swedish massage" the operator moves the limbs while the patient resists, thus bringing the opposing muscles into play. Sometimes the word "massage" is restricted to the rubbing processes, "manipulation" being used to cover all the movements mentioned.

Rubbing has been subdivided into several processes, namely (1) stroking, (2) kneading, (3) rubbing and (4) tapping, and great importance is attached to the application of a particular process in a particular way. Oils and other lubricants may or may not be used. But, however applied, the treatment acts essentially by increasing circulation and improving nutrition. It was shown by Lauder Brunton that more blood actually flows through the tissues during and after rubbing. The number of red corpuscles, and, to some extent, their haemoglobin value, are said to be increased (Mitchell). At the same time the movement of the lymph stream is accelerated. In order to assist the flow of blood and lymph, stroking is applied centripetally, *i.e.*, upwards along the limbs and the lower part of the body, downwards from the head. The effects of the increased physiological activity set up are numerous. Functional ability is restored to exhausted muscles by the removal of fatigue products and the induction of a fresh blood supply; congestion is relieved; collections of serous fluid are dispersed; secretion and excretion are stimulated; local and general nutrition are improved. These effects indicate the conditions in which massage may be usefully applied. Such are various forms of paralysis and muscular wasting, chronic and subacute affections of the joints, muscular rheumatism, sciatica and other neuralgias, local venous congestions, convalescent fractures of bones, sprains, contractions, obesity and chronic constipation. In certain other conditions massage gives relief, probably in large measure by suggestion

(*q.v.*). Such are insomnia, some forms of headache, hysteria and neurasthenia, disorders of the female organs, melancholia and other forms of insanity and morphinism.

The therapeutic value of massage when judiciously used is undoubted, but it is not appropriate for fevers, pregnancy, collections of pus, acute inflammation of the joints, inflamed veins, fragile arteries, wounds of the skin, and generally speaking, those conditions in which it is not desirable to increase the circulation, or the patient cannot bear handling.

Massage of the face and neck forms the basis of most systems of modern beauty culture. By stimulating circulation and the flow of lymph, by clearing the tissues of accumulated wastes and increasing their nutrition, massage has the effect of clearing and refining the skin and making the contours of the face and neck smooth and firm.

The revival of massage in Europe and America has called into existence a considerable number of professional operators, both male and female, who may be regarded as forming a branch of the nursing profession. Several things are required for a good operator. One is physical strength. Deep massage is very laborious work and cannot be carried on for even half an hour without unusual muscular power. A second important requirement is tactile and muscular sensibility. A person not endowed with a fine sense of touch and resistance is liable to exert too great or too little pressure; the one hurts the patient, the other is ineffective. Then skill and knowledge, which can only be acquired by a course of instruction, are necessary. Finally, the standard of personal character necessary is that required for the nursing profession in general. Massage should always be carried out under medical direction and in proper surroundings.

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MASSAGETAE (măs-săg′ĕ-tī), people described by Herodotus (i. 204–16; iv. 11, 172) as dwelling beyond the Araxes (Oxus) in what is now Balkh and Bokhara. It was against their queen Tomyris that Cyrus undertook the expedition in which according to one story he met his end. In their usages some tribes were nomads like the people of Scythia (*q.v.*), others with their community of wives and habit of killing and eating their parents recalled the Issedones (*q.v.*); while the dwellers in the islands of the river were fish-eating savages. Probably the name included all the barbarous north-eastern neighbours of the Persians. Herodotus says they only used gold and copper (or bronze), not silver or iron.

MASSA MARITTIMA, a town and episcopal see of the province of Grosseto, Tuscany, Italy, 24 m. N.N.W. of Grosseto direct and 16 m. by rail N.E. of Follonica (28 m. N.W. of Grosseto on the main coast railway), 1,444 ft. above sea-level. Pop. (1921) (town) 9,410; (commune) 15,484. The Romanesque cathedral (13th century) has a fine font (1267, with a cover of 1447) and a Gothic reliquary (1324) of the patron saint Cerbone. The battlemented municipal palace and other buildings of the 13th century are picturesque. Above the old town is a fortress built by the Sienese in 1337.

MASSASOIT (1580–1661), chief of the Wampanoag Indians, was born in the present limits of Massachusetts about 1580. His tribe of several thousand had been almost destroyed by an epidemic, supposed to be yellow fever, just before the arrival of the Mayflower. In March 1621, an Indian, Samoset, appeared at Plymouth and to the surprise of the Pilgrims spoke to them in English. He arranged for a meeting between his chief, Massasoit, and Governor Bradford. Massasoit appeared a week later, and signed a treaty of peace with the white men which remained inviolate for 54 years. In 1623, when he had been very ill, Edward Winslow visited him and effected a cure. In return for this kindness Massasoit revealed the plot of a neighbouring tribe to destroy the white men. *See* A. G. Weeks, *Massasoit of the Wampanoags* (1919).

MASSAWA or MASSOWAH, a town on the African coast of the Red sea, chief port of the Italian colony of Eritrea, in 15° 36′ N. and 39° 28′ E. Pop. (1931) 4,154 including 654 Europeans. The town stands at the north end of the bay of Massawa and is built partly on a small coral island of the same name—where was the original settlement—and partly on the islets of Tautlub and Sheik Said, and the neighbouring mainland. The harbour is formed by the channel between the island and the mainland. It affords good anchorage in from 5 to 9 fathoms. The town possesses several good public buildings, chiefly built of coral, as are the houses of the principal European and Arab merchants. Since 1912 a railway has connected Massawa with Asmara, the capital of the colony. Massawa is the port for northern Abyssinia (of which Eritrea was formerly a part) but commerce is hampered by the lack of rapid means of communication. The trade consists mainly in exporting hides, butter, cotton, coffee and civet, and importing European and Indian made cloth. In 1935 Massawa became the base for the Italian expedition against Ethiopia (*see* ERITREA).

The island of Massawa appears to have formed part of the Abyssinian dominions for many centuries. It was at Massawa (Matzua, as it is called by the Portuguese chroniclers) that Christopher da Gama and his comrades landed in July 1541 on their way to aid the Abyssinians against the Mohammedan invaders. Captured by the Turks in 1557, the island remained a Turkish possession over two hundred years, although James Bruce found in 1769 that the governor was paying half the customs receipts to the negus of Abyssinia in return for the protection of that monarch. At the close of the 18th century Massawa was held by the sherif of Mecca, and it afterwards passed to Mohammed Ali of Egypt. The Turks were reinstated about 1850, but in 1865 they handed the island back to Egypt for an annual tribute of 2½ million piastres. In Feb. 1885 Massawa was occupied by an Italian force, the Egyptian garrison stationed there being withdrawn in the November following. The port was the capital of the Italian colony until 1900 when the seat of administration was removed to Asmara.

MASSÉNA, ANDRÉ, duke of Rivoli, prince of Essling (1756–1817), the greatest of Napoleon's marshals, son of a small wine merchant, it is said of Jewish origin, was born at Nice on May 6, 1756. He began life as a cabin boy, but in 1775 enlisted in the Royal-Italien regiment. He quickly rose to be under-officer-adjutant; but he left the army in 1789, retired to his native city, and married. He left Italy, and joined the 3rd battalion of the volunteers of the Var in 1791, and by February 1792 was a lieutenant-colonel. He served in the army which occupied Nice, and in the advance to the Apennines which followed, his knowledge of the country and of the people was so useful that in December 1793 he was already a general of division. He won the battle of Saorgio in August 1794, and after many successes, on Nov. 23, 1795, he had the greatest share in the victory of Loano, won by Schérer over the Austrians and Sardinians. In Bonaparte's great campaign of 1796–97 Masséna was his most trusted general of division and won the crowning victory of Rivoli. During this campaign Bonaparte gave him the title of *enfant chéri de la victoire,* which he was to justify till he met the English in 1810. In 1798 he commanded the army of Rome for a short time, but was displaced by the intrigues of Berthier. Masséna's next important service was in command of the army in Switzerland, which united the army in Germany under Moreau, and that in Italy under Joubert. The archduke Charles and Suvórov, who had each been successful in Germany and in Italy, now turned upon him. He held his ground well against the archduke, and then suddenly, leaving Soult to face the Austrians, he transported his army to Zürich, where, on Sept. 26, 1799, he entirely defeated Korsakov. This campaign and battle placed his reputation on a level with that of his compatriot Bonaparte, and he might have made the revolution of Brumaire, but he was sincerely attached to the republic, and had no ambition. Bonaparte, now First Consul, sent him to command the débris of the army of Italy, and he defended Genoa from February to June to the very last extremity, giving time for Bonaparte to strike his great blow at Marengo. He now went to Paris, where he sat in the Corps Législatif in 1803, and

actually defended Moreau without drawing upon himself the ill-will of Napoleon, who well knew his honesty.

Marshal of France.—In 1804 he was made one of the first marshals of France of the new régime, and in 1805 was decorated with the Grand Eagle of the Legion of Honour. In that year Napoleon chose Masséna to keep in check the archduke Charles in Italy, while he advanced through Germany with the grand army. Masséna kept the archduke occupied till he received news of the surrender of Ulm, and then on Oct. 30, defeated him in the battle of Caldiero. After the peace of Pressburg, Masséna was ordered to take possession of the kingdom of Naples, and to place Joseph Bonaparte on the throne. He then distinguished himself in Poland. In 1808 he was made duke of Rivoli. In the campaign in 1809 at the battle of Aspern-Essling his magnificent leadership made what might have been an appalling disaster into a mere reverse of which the enemy could make no use. At Wagram Masséna, too ill to ride, directed from his carriage the movements of the right wing. He was created prince of Essling, and given the castle of Thouars.

Campaign in Spain.—Masséna was then ordered to Spain to "drive the English into the sea." (For campaigns of 1810 and 1811, the advance to and the retreat from Torres Vedras *see* PENINSULAR WAR.) Masséna himself, with some justice, ascribed his failure to the frequent disobedience of his subordinates Ney, Reynier and Junot. Though unsuccessful Masséna kept his army for five weary months close up to Wellington's impregnable position before retiring. His retreat through a devastated country was terrible, but his force of character kept his men together, and Ney showed his best side in brilliant rear-guard actions, until dismissed for a new act of insubordination. Soon Masséna was again ready to try his fortune, and he nearly defeated Wellington at Fuentes d'Oñoro, though much hampered by Bessières. His recall soon followed this and he returned home to find his prestige gone. The old marshal felt he had a right to complain of Ney and of Napoleon himself, and, it is said, opened communications with Fouché and the remnant of the republican party. Napoleon gave his greatest marshal no more employment in the field, but made him a territorial commandant at Marseilles. Louis XVIII. confirmed him in this command. When Napoleon returned from Elba, Masséna, probably by the advice of Fouché, kept Marseilles quiet to await events, the greatest service he could do the royalists, but afterwards imputed to him as a fault. After the second restoration Masséna was summoned to sit on the court-martial which tried Marshal Ney, but refused. He died on April 4, 1817, and was buried in Père-la-Chaise, with only the word "Masséna" upon his tombstone.

See Thiébault's *Éloge funèbre*, and Koch's *Mémoires de Masséna* (4 vols., 1849), a valuable work, carefully compiled. In more modern times E. Gachot has produced several important works dealing with Masséna's campaigns.

MASSENA, a village of St. Lawrence county, New York, U.S.A., on the Grass river, 3 m. from the St. Lawrence. It is served by the Grand Trunk and the New York Central railways. The population was 5,993 in 1920; 10,637 in 1930. It is surrounded by a farming and dairying region and has various manufacturing industries. Flour, paper and paper products, mica and aluminum ware are some of the leading products. The village was incorporated in 1886.

MASSENBACH, CHRISTIAN KARL AUGUST LUDWIG VON (1758–1827), Prussian soldier, was born at Schmalkalden (1758), and educated at Heilbronn and Stuttgart, devoting himself chiefly to mathematics. He became an officer of the Württemberg army in 1778, and left this for the service of Frederick the Great in 1782. After serving through the campaigns of 1793 and 1794 as a staff officer he published a number of memoirs on the military history of these years. He was chiefly occupied however with schemes for the reorganization of the then neglected general staff of the Prussian army, and many of his proposals were accepted. Bronsart von Schellendorf in his *Duties of the General Staff* says that "the organization which he proposed and in the main carried out survived even the catastrophes of 1806–1807, and exists even at the present moment in its original outline."

In 1805 came threats of the war with Napoleon, which Massenbach had strongly opposed. He was made quartermaster-general (chief of staff) to Prince Hohenlohe, over whom he soon obtained a fatal ascendancy. War was averted for a moment by the result of the battle of Austerlitz, but it broke out in earnest in October 1806. Massenbach's influence clouded all the Prussian operations. The battles of Jena and Auerstädt were lost, and the capitulation of Prince Hohenlohe's army was negotiated. Even suggestions of disloyalty were not wanting. He retired to his estate in the Posen province, and occupied himself in writing pamphlets, memoirs, etc. When his estates passed into the grand duchy of Warsaw, he chose to remain a Prussian subject, and on the outbreak of the war of liberation he asked in vain for a post on the Prussian staff. After the fall of Napoleon he took part in Württemberg politics, was expelled from Stuttgart and Heidelberg, and soon afterwards arrested at Frankfurt, delivered over to the Prussian authorities and condemned to fourteen years' fortress imprisonment for his alleged publication of state secrets in his memoirs. He was released in 1826. He died on Nov. 21, 1827, at his estate of Bialokoscz, Posen.

See a life by L. G. von Knesebeck (1924).

MASSENET, JULES EMILE FREDERIC (1842–1912), French composer, was born at Montaud, on May 12, 1842. He studied at the Paris Conservatoire, where he obtained the Grand Prix de Rome in 1863 with the cantata *David Rizzio*. Massenet's operas include *Hérodiade*, five acts (Brussels, 1881); *Manon*, five acts, opéra comique (1884); *Le Cid*, four acts, opéra (1885); *Esclarmonde*, four acts, opéra comique (1889); *Le Mage*, five acts, opéra (1891); *Werther*, four acts (Vienna, 1892); *Thaïs*, three acts, opéra (1894); *Le Portrait de Manon*, one act, opéra comique (1894); *La Navarraise*, two acts (Covent Garden, 1894); *Sapho*, opéra comique (1897); *Le Jongleur de Notre Dame* (Mentone, 1902). Massenet also wrote oratorios, orchestral suites, and songs. He was professor of composition at the Conservatoire from 1878 to 1896. His opera *Panurge* was written just before his death in Paris on Aug. 13, 1912

A full bibliography of his works is given in Séré, *Musiciens français d'aujourd'hui* (2nd ed. 1921). *See* also, J. E. F. Massenet, *My Recollections* (Boston, 1919); R. Brancour, *Massenet* (1922); L. Schneider, *Massenet 1842–1912* (1926).

MASSEY, SIR EDWARD (*c.* 1619–74/5) English soldier, was born at Coddington, Cheshire. In 1639 he was a captain of pioneers in the army of Charles I., but soon after the outbreak of Civil War he went over to the parliamentarians. As lieutenant-colonel under the earl of Stamford he became, in 1643, governor of Gloucester, which he defended against the Royalists. In 1644 he was made general of the forces of the Western Association, and until 1645 played an important part in the war in the surrounding district. He became M.P. for Gloucester in 1646 and was one of the generals impeached by the army on the ground that they were attempting to revive the Civil War in the Presbyterian interests. Massey fled from England in June 1647, and though he resumed his seat in the house in 1648 he was again excluded by Pride's Purge, and after a short imprisonment escaped to Holland. Thence, openly taking the side of the king, he accompanied Charles II. to Scotland. He fought at the bridge of Stirling and Inverkeithing, and commanded the advanced guard of the Royalists in the invasion of England in 1651. Near Worcester he fell into the hands of his former comrades and was lodged in the Tower. He again escaped to Holland, and on Charles's return, was knighted and given a grant of £3,000. He is said to have died in Ireland.

MASSEY, GERALD (1828–1907), English poet, was born near Tring, Hertfordshire, on May 29, 1828. As a child he was sent to work in a silk factory, and afterwards at straw-plaiting. He struggled manfully against the distress and deprivations of his early years, and educated himself in his spare time. He threw himself into the movement known as Christian Socialism (*q.v.*), becoming associated with Maurice and Kingsley. He first became known as editor of the *Spirit of Freedom*, and at the age of 22 published his first volume of poems, *Voices of Freedom and*

Lyrics of Love. Massey's poetry has a certain rough and vigorous element of sincerity and strength which accounts for its popularity at that time. He also wrote several popular books on Egypt including *The Book of the Beginnings,* followed by *The Natural Genesis;* but his most important work is *Ancient Egypt: The Light of the World,* published shortly before his death. He died on Oct. 29, 1907. The best of his poems were collected by him in *My Lyrical Life* (2 vols., 1889); he also published works dealing with spiritualism, the study of Shakespeare's sonnets, and theological speculation.

See J. Churton Collins' article, *Contemporary Review* (May 1904).

MASSEY, WILLIAM FERGUSON (1856–1925), New Zealand statesman, was born at Limavady, Co. Derry, Ireland, on March 26, 1856. His parents emigrated to New Zealand when he was six, and eight years later he joined them at Tamaki. After an elementary education, he went on the land, and 20 years later, as president of the Auckland Agricultural and Pastoral Society, began to play a prominent part in public life. He entered parliament in 1894 as member for Waitemata, and in 1903 became leader of the Conservative opposition to Seddon and Sir Joseph Ward. In 1912 he defeated the ministry and formed a cabinet. Thereafter he played a dominating part in the Dominion's affairs. His strong personality, sterling honesty of purpose and administrative ability commanded universal respect, and during the World War, at the head of a strong Coalition ministry, which included his lifelong opponent, Ward, Massey led New Zealand with conspicuous ability and foresight. And, just as he had not hesitated to introduce conscription without reference to the people, so he had the courage, when peace came, to enforce unpopular economies. He was a member of the Imperial War cabinet in 1917–18 and in 1919 was the representative of New Zealand at the Peace Conference in Paris. Shortly after the Imperial Conference of 1923 his health gave way, and he died on May 10, 1925.

MASSICUS, MONS, a mountain ridge of ancient Italy, in the territory of the Aurunci. It projects in a south-westerly direction from the volcanic system of Rocca Monfina as far as the sea, and separates the lower course of the Liris from the plain of Campania. It consists of limestone, with a superstratum of pliocenic and volcanic masses, and was once an island; its highest point is 2,661 ft. above sea-level. It is now traversed by a long tunnel of the new direct railway to Naples.

It was very famous for its wine in ancient times. There was just room along the coast for the road to pass through; the pass was guarded by the Auruncan town of Vescia, which ceased to exist in 314 B.C. after the defeat of the Ausones. Its successor, Sinuessa, on the coast, a station on the Via Appia, was constructed in 312 B.C. Domitian considerably increased its importance by the construction of the Via Domitiana, which left the Via Appia here and ran to Cumae and Puteoli. The town was destroyed by the Saracens, but ruins are still visible two miles north-west of the modern Mondragone.

MASSIF, a French term, adopted in geomorphology for a mountainous mass of connected heights, whether isolated or forming part of a larger system. A "massif" is usually clearly marked off by valleys.

MASSILLON, JEAN BAPTISTE (1663–1742), French bishop and preacher, was born at Hyères on June 24, 1663, his father being a royal notary of that town. At the age of eighteen he joined the Congregation of the Oratory and taught for a time in the colleges of his order at Pézenas, and Montbrison and at the Seminary of Vienne. In 1693 he was placed at the head of the famous seminary of Saint Magloire. He soon gained a wide reputation as a preacher and was selected to be the Advent preacher at the court of Versailles in 1699. He was made bishop of Clermont in 1717, and two years later was elected a member of the French Academy. The last years of his life were spent in the faithful discharge of his episcopal duties; his death took place at Clermont on Sept. 18, 1742. Massillon enjoyed in the 18th century a reputation equal to that of Bossuet and of Bourdaloue, and has been much praised by Voltaire, D'Alembert and kindred spirits among the *Encyclopaedists.* He has usually been contrasted with his predecessor Bourdaloue, the latter having the credit of vigorous denunciation, Massillon that of gentle persuasiveness. Besides the *Petit Carême,* a sermon which he delivered before the young king Louis XV. in 1718, his sermons on the Prodigal Son, on the small number of the elect, on death, for Christmas Day, and for the Fourth Sunday in Advent, may be perhaps cited as his masterpieces. His funeral oration on Louis XIV. is remembered for the opening sentence: "Dieu seul est grand."

The first edition of Massillon's complete works was published by his nephew, also an Oratorian (Paris, 1745–48), and upon this, in the absence of mss., succeeding reprints were based. The best modern edition is that of the Abbé Blampignon (Paris, 1865–68, 4 vols.; new ed. 1886).

See Abbé Blampignon, *Massillon, d'après des documents inédits* (Paris, 1879); and *L'Épiscopat de Massillon d'après des documents inédits, suivi de sa correspondance* (Paris, 1884); F. Brunetière "L'Éloquence de Massillon" in *Études critiques* (Paris, 1882); Père Ingold, *L'Oratoire et le jansénisme au temps de Massillon* (Paris, 1880); Pauthe, *Massillon, sa prédication sous Louis XIV. et Louis XV.* (1908).

MASSILLON, a city of Stark county, Ohio, U.S.A., on the Tuscarawas river, at an altitude of 1,000 ft., 8 m. W. of Canton It is on Federal highways 21 and 30 (the Lincoln) and is served by the Baltimore and Ohio, the Pennsylvania and the Wheeling and Lake Erie railways, inter-urban trolleys, and motor-bus lines. Pop 17,428 in 1920 (86% native white); in 1930 (after annexations of territory) it had grown to 26,400. It is a manufacturing centre with diversified industries, and a distributing point for bituminous coal from Ohio and West Virginia. The manufactures include alloy and cold-drawn steels, aluminum and enamelled ware, marine engineering and shipping equipment. A State hospital for the insane is located here. Massillon was founded in 1826, incorporated as a village in 1853 and as a city in 1868. It was named after Jean Baptiste Massillon.

MASSIMO or **MASSIMI,** a Roman princely family of great antiquity, said to be descended from the ancient Maximi of republican Rome. The name is first mentioned in 1012 in the person of Leo de Maximis, and the family played a considerable part in the history of the city in the middle ages. The brothers Pietro and Francesco Massimi protected the German printer Ulrich Hahn, who came to Rome in 1467. In the 16th century the Massimi were the richest of the Roman nobles. A marquisate was conferred on them in 1544, and the lordship of Arsoli in 1574. To-day there are two branches of the Massimi, viz., the Principi Massimo, descended from Camillo Massimiliano (1770–1840), and the dukes of Rignano, descended from Francesco Massimo (1773–1844). The Palazzo Massimo, one of the finest Renaissance buildings in Rome, was built by Baldassare Peruzzi by order of Pietro Massimo, on the ruins of an earlier palace destroyed in the sack of Rome in 1527.

See F. Gregorovius, *Geschichte der Stadt Rom* (1880); A. von Reumont, *Geschichte der Stadt Rom* (1868); *Almanach de Gotha;* J. H. Douglas, *The Principal Noble Families of Rome* (1905).

MASSINGER, PHILIP (1583–1640), English dramatist, son of Arthur Massinger or Messanger, was baptized at St. Thomas's, Salisbury, on Nov. 24, 1583. He entered St. Alban hall, Oxford, in 1602. His father was attached to the household of the 2nd Earl of Pembroke, but on the succession of William Herbert in 1601 it has been suggested that the patronage ceased. On the other hand, à Wood says that he went to Oxford at Lord Pembroke's expense. Massinger left Oxford without a degree in 1606. His father had died in 1603, and he was perhaps dependent on his own exertions. He went to London to work as a dramatist, but his name cannot be definitely affixed to any play until fifteen years later, when *The Virgin Martyr* (ent. at Stationers' hall, Dec. 7, 1621) appeared as the work of Massinger and Dekker. During these years he worked in collaboration with other dramatists. From 1613 Massinger apparently worked regularly with John Fletcher, although in editions of Beaumont and Fletcher's works his co-operation is usually unrecognized.

Sir Aston Cokayne, Massinger's constant friend and patron, refers in explicit terms to this collaboration in a sonnet addressed to Humphrey Moseley on the publication of his folio edition of Beaumont and Fletcher (*Small Poems of Divers Sorts,* 1658), and in an epitaph on the two poets he says:—

Plays they did write together, were great friends,
And now one grave includes them in their ends.

After Philip Henslowe's death in 1616 Massinger and Fletcher began to write for the King's Men. Between 1623 and 1626 Massinger produced unaided for the Lady Elizabeth's Men then playing at the Cockpit three pieces, *The Parliament of Love, The Bondman* and *The Renegado*. With the exception of these plays and *The Great Duke of Florence,* produced in 1627 by the Queen's servants, Massinger continued to write regularly for the King's Men until his death. S. R. Gardiner, in an essay on "The Political Element in Massinger" (*Contemp. Review*, Aug. 1876), maintained that Massinger's dramas are before all else political.

In 1631 Sir Henry Herbert, the master of the revels, refused to license an unnamed play by Massinger because of "dangerous matter as the deposing of Sebastian, King of Portugal," calculated presumably to endanger good relations between England and Spain. There is little doubt that this was the same piece as *Believe as You List,* in which time and place are changed, Antiochus being substituted for Sebastian, and Rome for Spain.

Massinger seems to have supported the democratic views of his patron, the Earl of Montgomery, who was an enemy of Buckingham. In *The Bondman,* dealing with the history of Timoleon, Buckingham is satirized as Gisco. The servility towards the Crown displayed in Beaumont and Fletcher's plays reflected the temper of the court of James I. The attitude of Massinger's heroes and heroines towards kings is very different. Camiola's remarks on the limitations of the royal prerogative (*Maid of Honour,* act IV., sc. V.) could hardly be acceptable at court.

Massinger died suddenly at his house near the Globe theatre, and was buried in the churchyard of St. Saviour's, Southwark, on March 18, 1640.

The supposition that Massinger was a Roman Catholic rests upon three of his plays, *The Virgin Martyr* (licensed 1620), *The Renegado* (licensed 1624) and *The Maid of Honour* (*c.* 1621). *The Virgin Martyr,* which deals with the martyrdom of Dorothea in the time of Diocletian, cannot be relied on. It is not entirely his work, and the story is early Christian, not Roman Catholic. In *The Renegado,* however, the action is dominated by the beneficent influence of a Jesuit priest, Francisco, and the doctrine of baptismal regeneration is enforced. In *The Maid of Honour* a complicated situation is solved by the decision of the heroine, Camiola, to take the veil.

His plays have generally an obvious moral intention. He sets himself to work out a series of ethical problems through a succession of ingenious and effective plots. In the art of construction he has, indeed, few rivals. But the virtue of his heroes and heroines is rather morbid than natural, and often singularly divorced from common-sense. His *dramatis personae* are in general types rather than living persons, and their actions do not appear to spring inevitably from their characters, but rather from the exigencies of the plot. The heroes are too good, and the villains too wicked to be quite convincing. Moreover their respective goodness and villainy are too often represented as extraneous to themselves. This defect of characterization shows that English drama had already begun to decline. He contributed, however, at least one great and popular character to the English stage. Sir Giles Overreach, in *A New Way to Pay Old Debts,* is a sort of commercial Richard III., a compound of the lion and the fox, and the part provides many opportunities for a great actor. He made another considerable contribution to the comedy of manners in *The City Madam.* In Massinger's own judgment *The Roman Actor* was "the most perfect birth of his Minerva." It is a study of the tyrant Domitian, and of the results of despotic rule on the despot himself and his court.

Massinger was a student and follower of Shakespeare. The form of his verse, especially in the number of run-on lines, approximates in some respects to Shakespeare's later manner. He is rhetorical and picturesque, but rarely rises to extraordinary felicity. His verse is never mean, but it sometimes comes perilously near to prose, and in dealing with passionate situations it lacks fire and directness.

The plays attributed to Massinger alone are: *The Duke of Milan, a Tragedy* (*c.* 1618, pr. 1623 and 1638); *The Unnatural Combat, a Tragedy* (*c.* 1619, pr. 1639); *The Bondman, an Antient Storie* (licensed 1623, pr. 1624); *The Renegado, a Tragaecomedie* (lic. 1624, pr. 1630); *The Parliament of Love* (lic. 1624; ascribed, no doubt erroneously, in the Stationers' Register, 1660, to W. Rowley; first printed by Gifford from an imperfect ms. in 1805); *A New Way to Pay Old Debts, a Comoedie* (*c.* 1625, pr. 1632); *The Roman Actor, A Tragaedie* (lic. 1626, pr. 1629); *The Maid of Honour* (dating perhaps from 1621, pr. 1632); *The Picture, a Tragecomedie* (lic. 1629, pr. 1630); *The Great Duke of Florence, a Comicall Historie* (lic. 1627, pr. 1635); *The Emperor of the East, a Tragaecomoedie* (lic. and pr. 1631), founded on the story of Theodosius the Younger; *Believe as You List* (rejected by the censor in January, but licensed in May, 1631; pr. 1848–49 for the Percy Society); *The City Madam, a Comedie* (lic. 1632, pr. 1658), which Mr. Fleay (*Biog. Chron. of the Eng. Drama,* i. 226), however, considers to be a *rifaciamento* of an older play, probably by Jonson; *The Guardian* (lic. 1633, pr. 1655); and *The Bashful Lover* (lic. 1636, pr. 1655). *A Very Woman, or The Prince of Tarent,* licensed in 1634 as the work of Massinger alone, is generally referred to his collaboration with Fletcher.

Twelve plays of Massinger are said to be lost, but the titles of some of these may be duplicates of those of existing plays. Five of these lost plays were mss. used by John Warburton's cook for pie-covers. The numerous plays in which Massinger's co-operation with John Fletcher is generally assumed are dealt with under BEAUMONT and FLETCHER. But it may be here noted that Mr. R. Boyle has constructed an ingenious case for the joint authorship by Fletcher and Massinger of the two "Shakespearian" plays, *Henry VIII.* and *Two Noble Kinsmen.* (*See* the New Shakspere Society's *Transactions,* 1884 and 1882.)

Massinger's independent works were collected by Coxeter (4 vols, 1759, revised edition with introduction by Thomas Davies, 1779), by J. Monck Mason (4 vols., 1779), by William Gifford (4 vols, 1805, 1813), by Hartley Coleridge (1840), by Lieut.-Colonel Cunningham (1867), and selections by Mr. Arthur Symons in the *Mermaid Series* (1887–89). Gifford's remains the standard edition, and formed the basis of Cunningham's text. It contains "An Essay on the Dramatic Writings of Massinger" by Dr. John Ferriar.

Massinger has been the object of a good deal of criticism. A metrical examination of the plays in which Massinger was concerned is given in *Englische Studien* (Halle, v. 74, vii. 66, viii. 39, ix. 209 and x. 383), by Mr. R. Boyle, who also contributed the life of the poet in the *Dictionary of National Biography.* The sources of his plays are dealt with by E. Koeppel in *Quellen Studien zu den Dramen Chapman's, Massinger's und Ford's* (Strassburg, 1897). For detailed criticism, beside the introductions to the editions quoted, *see* A. W. Ward, *Hist. of Eng. Dram. Lit.* (1899), iii. 1–47; F. G. Fleay, *Biog. Chron. of the Eng. Drama* (1891), under *Fletcher;* and Koeppel in *Cambridge History of English Literature,* vol. vi.; a general estimate of Massinger, dealing especially with his moral standpoint, is given in Sir Leslie Stephen's *Hours in a Library* (3rd series, 1879); Swinburne, in the *Fortnightly Review* (July 1889), while acknowledging the justice of Sir L. Stephen's main strictures, found much to say in praise of the poet. Full discussion of the disputed plays will be found in A. H. Cruickshank, *Philip Massinger* (Oxford, 1928); *see* also the list which will be found at the end of ch. 5, *Cambridge History of English Literature,* vol. vi. (1910).

MASSINGHAM, HENRY WILLIAM (1860–1924), British journalist, was born at Old Catton, Norfolk. He commenced journalism at the age of 17, and, after serving on various newspapers, he began, in 1907, a long association with *The Nation,* which he edited till the end of 1923. He was a severe critic of the World War and the Peace Treaty of 1919 and advocated co-operation between the Liberal and Labour parties. An early member of the Fabian Society, Massingham ultimately joined the Labour party, though on ethical, rather than economic, grounds, and his last journalistic work was done for *The New Statesman.* He died at Tintagel, Cornwall, on Aug. 28, 1924. One of the best all-round journalists of his day, he was a trenchant writer on politics and a discerning critic of literature and the drama. He published in 1892 *The London Daily Press,* and contributed an introduction to the memorial edition of the works of Mark Rutherford (1923).

H. W. M. A Selection from the Writings of H. W. Massingham, ed. by H. J. Massingham (1925), contains highly appreciative estimates by G. Bernard Shaw and various eminent associates.

MASSINISSA (*c.* 238–149 B.C.), king of Massylian or eastern Numidia, was educated at Carthage. His kingdom, though nominally independent of Carthage, was imbued to a very considerable extent with Carthaginian civilization; Massinissa, though a barbarian at heart, had a varnish of culture, and the craft and cunning in which Carthaginian statesmen were supposed to

excel. While yet a young man (212) he forced his neighbour Syphax, prince of western Numidia, who had recently entered into an alliance with Rome, to fly to the Moors in the extreme west of Africa. Soon afterwards he appeared in Spain, fighting for Carthage with a large force of Numidian cavalry against the Romans under the two Scipios. The defeat of the Carthaginian army in 206 led him to cast in his lot with Rome. Scipio Africanus is said to have cultivated his friendship. Massinissa now quitted Spain for a while for Africa, and was again engaged in a war with Syphax in which he was decidedly worsted, but after Scipio's arrival in Africa in 204 Massinissa crushed his old enemy Syphax, and captured his capital Cirta (Constantine).

Here occurs the romantic story of Sophonisba, daughter of the Carthaginian Hasdrubal, who had been promised in marriage to Massinissa, but had subsequently become the wife of Syphax. Massinissa, according to the story, married Sophonisba immediately after his victory, but was required by Scipio to dismiss her as a Carthaginian, and consequently an enemy to Rome. To save her from such humiliation he sent her poison, with which she destroyed herself. Massinissa was now confirmed by Scipio in the possession of his kingdom. In the battle of Zama (202) (*see* PUNIC WARS), he commanded the cavalry on Scipio's right wing. For his services he received the kingdom of Syphax, and thus under Roman protection he became master of the whole of Numidia, and his dominions completely enclosed the Carthaginian territories. It would seem that he had thoughts of annexing Carthage itself with the connivance of Rome. In a war which soon followed he was successful; the remonstrances of Carthage with Rome on the behaviour of her ally were answered by the appointment of Scipio as arbitrator; but, as though intentionally on the part of Rome, no definite settlement was arrived at. Rome, it is certain, deliberately favoured her ally's unjust claims with the view of keeping Carthage weak, and it was Massinissa's policy, as soon as Carthage seemed to be recovering herself, to excite the fears of Rome, till at last the Third Punic War (149) ended in the final overthrow of Carthage. The king died soon after its commencement.

Massinissa converted a plundering tribe into a settled and civilized population. To his sons he bequeathed a well-stored treasury, a formidable army, and even a fleet. Cirta (*q.v.*), his capital, became a famous centre of Phoenician civilization. In fact Massinissa changed for the better the whole aspect of a great part of northern Africa. His fidelity to Rome was merely that of temporary expediency.

See Livy xxiv. 49, xxviii. 11, 35, 42, xxix. 27, xxx. 3, 12, 28, 37, xlii. 23, 29, xliii. 3; Polybius iii. 5 ix. 42, xiv. 1, xxxii. 2, xxxvii. 3; Appian, *Hisp.* 37, *Punica,* 11, 27, 105; Justin xxxiii. 1; A. H. J. Greenidge, *Hist. of Rome* (1904).

MASSON, DAVID (1822–1907), Scottish man of letters, was born at Aberdeen on Dec. 2, 1822, and educated at the grammar school there and at Marischal College. He studied theology at Edinburgh university, under Dr. Chalmers. He gave up his intention to enter the ministry, and became editor of the *Banner,* a weekly paper which advocated Free Church principles. After two years he returned to Edinburgh, where he became a frequent contributor to *Fraser's Magazine, Dublin University Magazine* (in which appeared his essays on Chatterton), and other periodicals. In 1847 he went to London, where he became secretary (1851–2) of the "Society of the Friends of Italy." In 1852 he was appointed professor of English literature at University college, London, and from 1858 to 1865 he edited the newly established *Macmillan's Magazine.* From 1865–93 he occupied the chair of rhetoric and English literature at Edinburgh, and promoted the movement for the university education of women. In 1879 he became editor of the Register of the Scottish Privy Council, and in 1893 was appointed Historiographer Royal for Scotland. His *magnum opus* is his *Life of Milton in Connexion with the History of His Own Time* (6 vols. 1858–80). He also edited the library edition of Milton's *Poetical Works* (3 vols., 1874), and De Quincey's *Collected Works* (14 vols., 1889–90). He died on Oct. 6, 1907. Professor Masson had married Rosaline Orme. His son Orme Masson became professor of chemistry in the university of Melbourne.

Among his other publications are *Essays, Biographical and Critical* (1856, reprinted with additions, 3 vols., 1874), *British Novelists and their Styles* (1859), *Drummond of Hawthornden* (1873), *Chatterton* (1873) and *Edinburgh Sketches* (1892).

MASSON, FRÉDÉRIC (1847–1923), French historian and academician was born in Paris on March 8, 1847. His father, Francis Masson, a solicitor, was killed on June 23, 1848, while serving as an officer in the *garde nationale.* Young Masson was educated at the college of Sainte Barbe, and at the lycée Louis-le-Grand, and then travelled in Germany and in England; from 1869 to 1880 he was librarian at the Foreign Office. He is best known for his books connected with Napoleon. In *Napoléon inconnu* (1895), Masson, with M. Guido Biagi, brought out the unpublished writings (1786–1793) of the future emperor. These were notes, extracts from historical, philosophical and literary books, and personal reflections. His other works include several books on Josephine; *Napoléon et sa famille* (9 vols., 1897–1907); *Napoléon et son fils* (1904); and *Autour de l'Île d'Elbe* (1908). Masson died in Paris on Feb. 19, 1923.

A bibliography of his works, including anonymous ones and those under an assumed name, has been published by G. Vicaire (*Manuel de l'amateur des livres du XIX^e siècle,* tome v., 1904).

MASS PRODUCTION. The term mass production is used to describe the modern method by which great quantities of a single standardized commodity are manufactured. As commonly employed it is made to refer to the quantity produced, but its primary reference is to method. In several particulars the term is unsatisfactory. Mass production is not merely quantity production, for this may be had with none of the requisites of mass production. Nor is it merely machine production, which also may exist without any resemblance to mass production. Mass production is the focussing upon a manufacturing project of the principles of power, accuracy, economy, system, continuity and speed. The interpretation of these principles, through studies of operation and machine development and their co-ordination, is the conspicuous task of management. And the normal result is a productive organisation that delivers in quantities a useful commodity of standard material, workmanship and design at minimum cost. The necessary, precedent condition of mass production is a capacity, latent or developed, of *mass consumption,* the ability to absorb large production. The two go together, and in the latter may be traced the reasons for the former.

I. THE ORIGINS OF MASS PRODUCTION

In origin mass production is American and recent; its earliest notable appearance falls within the first decade of the 20th century. The mere massing of men and materials is a procedure as old as the pyramids. Basic industries, like weaving, domestic baking, house construction and wooden ship building, are carried on, with only superficial changes, much as they were in ancient Egypt. Cottage manufactures and handicrafts moulded the practices of industry until the invention of the steam-engine. With the coming of power machines the seat of industry was removed from the homes of the people and a new work centre, the factory, was established. Much harsh criticism has been uttered against "the factory system," but it is perhaps fair to say that its first effect was to emancipate the home from being a mere adjunct to the loom or bench, and its later effect was to provide the home with means to develop the dignified status which it has now attained.

The Factory System Giving Way.—The early factory system was uneconomical. Its beginning brought greater risk and loss of capital than had been known before, lower wages and more precarious outlook for the workers, and a decrease in quality of goods. More hours, more workers, more machines did not improve conditions; every increase did but enlarge the scale of fallacies built into business. Mere massing of men and tools was not enough; the profit motive, which dominated enterprise, was not enough. There remained the scientific motive which grew eventually into what is called mass production.

The new method came after the failure of the mercantile and

financial emphasis in manufacture. The advent and progress of financial control of industry were marked by two developments, the corporation and the labour revolt. Artificial combination of industrial plants into vast corporations for financial purposes was the first movement toward *mass* in industry. It proceeded on the theory that complete financial control would automatically bring complete profit advantage. The theory ignored many vital principles of business and its fallacy became apparent, but not before serious social hostility had been incurred.

However, it was out of the social strife thus engendered that the idea began to emerge that possibly the difficulty lay in the neglect of scientific manufacturing principles. Industry was conceded to be necessary and useful; the service it rendered was regarded as of sufficient value to afford fair compensation for all engaged in it; it was therefore urged that the attention of management should be more directly focussed on the actual labour processes that were employed. This led to what was known early in the 20th century as the "efficiency movement" with its accompaniments of time-study and similar methods, although its roots were laid in the experiences of sound industrial observers as early as 1878. It cannot be said, however, that the efficiency experts did more than direct attention to the problem, by showing, in selected instances, how the then current methods were wasteful of men's earning power, and how their correction and improvement could lead to greater production, hence higher wages, and therefore a general betterment of labour relations. They emphasized a more intelligent management of methods than was then in use; they did not see that a wholly new method was possible which would simply abolish the problems of which the old method, under the most intelligent management, was inevitably prolific. For example they dealt with methods which enabled labourers whose task was to load 12½ tons of pig-iron a day, to load 47½ long tons a day for an increase in the day's pay from $1.15 to $1.85. They did not see that another and better method might be devised which would make it unnecessary for a working-man to carry 106,400 lb. of pig-iron to earn $1.85. Mass production was not in their view, but only the alleviation of the worst errors of competitive factory practice.

The Motor Industry Leads the Way.—To the motor industry is given the credit of bringing mass production to experimental success, and by general consent the Ford Motor Company is regarded as having pioneered in the largest development of the method under a single management and for a single purpose. It may, therefore, simplify the history of mass production and the description of its principles if the experience of this company is taken as a basis. It has been already suggested that mass production is possible only through the ability of the public to absorb large quantities of the commodity thus produced. These commodities are necessarily limited to necessities and conveniences. The greatest development of mass production methods has occurred in the production of conveniences. The motor vehicle represents a basic and continuous convenience-transportation.

Mass production begins, then, in the conception of a public need of which the public may not as yet be conscious and proceeds on the principle that use-convenience must be matched by price-convenience. Under this principle the element of service remains uppermost; profit and expansion are trusted to emerge as consequences. As to which precedes the other, consumption or production, experiences will differ. But granted that the vision of the public need is correct, and the commodity adapted to meet it, the impulse to increased production may come in anticipation of demand, or in response to demand, but the resulting consumption is always utilized to obtain such increase of quality, or such decrease of cost, or both, as shall secure still greater use-convenience and price-convenience. As these increase, consumption increases, making possible still greater production advantages, and so on to a fulfilment that is not yet in view.

The commodities that conduce to civilized living are thus far enjoyed by only a small fraction of the world's inhabitants. The experience of the Ford Motor Company has been that mass production precedes mass consumption and makes it possible, by reducing costs and thus permitting both greater use-convenience and price-convenience. If the production is increased, costs can be reduced. If production is increased 500% costs may be cut 50%, and this decrease in cost, with its accompanying decrease in selling price, will probably multiply by 10 the number of people who can conveniently buy the product.

II. THE PRINCIPLES OF MASS PRODUCTION

As to shop detail, the keyword to mass production is simplicity. Three plain principles underlie it: (*a*) the planned orderly progression of the commodity through the shop; (*b*) the delivery of work instead of leaving it to the workman's initiative to find it; (*c*) an analysis of operations into their constituent parts. These are distinct but not separate steps; all are involved in the first one. To plan the progress of material from the initial manufacturing operation until its emergence as a finished product involves shop planning on a large scale and the manufacture and delivery of material, tools and parts at various points along the line. To do this successfully with a progressing piece of work means a careful breaking up of the work into its "operations" in sequence. All three fundamentals are involved in the original act of planning a moving line of production.

This system is practised, not only on the final assembly line, but throughout the various arts and trades involved in the completed product. The motor car assembly line offers an impressive spectacle of hundreds of parts being quickly put together into a going vehicle, but flowing into that are other assembly lines on which each of the hundreds of parts have been fashioned. It may be far down the final assembly line that the springs, for example, appear, and they may seem to be a negligible part of the whole operation. Formerly one artisan would cut, harden, bend and build a spring. In 1928 the making of one leaf of a spring is an operation of apparent complexity, yet is really the ultimate reduction to simplicity of operation.

A Typical Operation Described.—For its illustrative value let us trace the course of a spring leaf after it has progressed from iron ore through ingot, bloom and billet stages, and is rolled into strips. (1) Beginning as a strip of steel prepared by the steelmill, it is placed in a punch press for cutting and piercing. The workman puts the strip into press until it hits a stop, then trips the press. The cut-off and pierced piece falls on a belt conveyor which runs along the loading end of a series of heat-treating ovens. (2) A second workman takes the pieces from belt conveyor and places them on conveyor which passes through the furnace (in which temperature is automatically controlled); thence they are deposited at a certain temperature by this conveyor at the unloading end of the furnace. (3) The heated piece is lifted with tongs by a third operator and placed in a bending machine which gives the leaf its proper curve and plunges it in oil, the temperature of which is maintained at a definite degree by apparatus beyond the operator's control. (4) As the bending machine emerges from the oil bath, the same operator takes out the leaf and sets it aside to air-cool. (5) The leaf is then drawn by a fourth operator through molten nitrate kept at a regulated temperature. (6) A fifth workman inspects it.

As a set of springs on the Ford car requires on an average 17 leaves, and 25,000 springs are an average day's output, this operation must be visualised as employing a great battery of lines similar to the one briefly described. As all the leaves in a spring are of different length and curve, from the bottom or master leaf to the top leaf, this operation must be visualised as one of many carried on simultaneously by different batteries of machines, each battery working on its own special size. All of these lines, with their various machines and operations, are converging on the point where the leaves are assembled into springs. The leaf whose progress has been described is the simplest one.

The operation proceeds as follows: (7) A sixth workman removes the leaf from the conveyor which carries it from the molten nitrate, and inserts a bolt through this and the other leaves required in the spring. (8) A seventh workman puts the nut on the bolt and tightens it. (9) An eighth workman puts on the right and left hand clips and grinds off the burrs. (10) A ninth workman inspects it. (11) He hangs the spring on a conveyor. (12) The

spring passes the tenth workman, who sprays it with paint, and the conveyor carries the spring above the ovens where it was originally heated, and the radiated heat "force dries" the paint. (13) The conveyor continues to the loading dock, where the eleventh workman removes it.

One workman under the old system could attend the leaf through all these phases, or even make a complete spring, but his production would be limited. Where large quantities of the same article are to be made, the simplest operation may involve the whole time of one man. A one-minute operation will require one man a full day of eight hours to accomplish it on 480 pieces. Now this simple part, a spring leaf, must be identical in strength, finish and curve with millions of others designed to fulfil the same purpose, and this becomes a complicated and delicate procedure requiring automatic machinery, the most accurate of measuring devices, pyrometer controls, "go" and "no go" gauges—in fact, the best facilities that can be provided by modern management. The leaf described, which is a minor matter when compared with the whole great process, becomes a major matter when considered by itself; it must have its own supply of material delivered in sufficient quantities at indicated places—for example, steel at 1; heat at 2; power and oil at 3; molten nitrate at 5; bolts at 7; nuts at 8; clips at 9; paint at 12. In this process the secrets of many arts and trades are employed

The story of this minor part illustrates what is meant by orderly progression of the article through the shop. It goes to meet other parts of the motor-car which have come from other parts of the plant by similar processes. The story illustrates also what is meant by delivering the work to the workman: every workman's task is prepared for him by some other workman, and delivered to his hand. The third principle also is illustrated—the analysis of a single job into its constituent operations. The simplicity of the part here described should not be permitted to exclude from view the multitude of other operations, ranging from the heaviest forgings to the lightest manipulations in bench assembly of delicate electrical instruments. Some gauge inspections involve measurements to the ten-millionth part of an inch.

The economies arising from this method are obvious. The machinery is constantly in use. It would be economically impossible to maintain all this equipment for the service of men occupied in the entire operation of making springs. Presses, furnaces, bending machines, oil baths would be idle while the workman progressed from operation to operation. Under mass production it is the work that progresses from operation to operation. Use-convenience in the commodity would be lessened, while price-convenience would be destroyed. Economy in machine hours is, however, only one element; there is also economy in time and material and labour. Mass production justifies itself only by an economy whose benefits may be transmitted to the purchaser.

III. THE EFFECTS OF MASS PRODUCTION

But it is not the history and principle of mass production which provoke the widest discussions; the *effects* of it have been placed under scrutiny. What have been the effects of mass production on society?

(1) Beginning with management, where unquestionably mass production methods take their rise, there is a notable increase in industrial control, as distinguished from financial control. The engineer's point of view has gained the ascendancy and this trend will undoubtedly continue until finance becomes the handmaid instead of the mistress of productive industry. Industrial control has been marked by a continuous refinement of standardization, which means the instant adoption of the better method to the exclusion of the old, in the interests of production. Financial control was not, in its heyday, marked by a tendency to make costly changes in the interests of the product. The economy of scrapping the old equipment immediately upon the invention of the better equipment was not so well understood. It was engineering control, entrenched in mass production methods, that brought in this new readiness to advance. In this way management has been kept close to the shop and has reduced the office to a clearing house for the shop. Managers and men have been brought into closer contact and understanding. Manufacturing has been reduced to greater singleness of purpose.

(2) The effect of mass production on the product has been to give it the highest standard of quality ever attained in output of great quantities. Conditions of mass production require material of the best quality to pass successfully through the operations. The utmost accuracy must control all these operations. Every part must be produced to fit at once into the design for which it is made. In mass production there are no fitters. The presence of fitters indicates that the parts have been produced unfit for immediate placement in the design. In works of art and luxury this accuracy is achieved at the cost of careful handiwork. To introduce hand methods of obtaining accuracy into mass production would render mass production impossible with any reference to price-convenience. The standard quality of the product is guaranteed by the fact that machines are so constructed that a piece of work cannot go through them unless it exactly accords with specifications. If the work goes through the tools, it must be right. It will thus be seen that the burden of creation is on management in designing and selecting the material which is to be produced by the multiple processes utilised in mass production.

(3) The effect of mass production on mechanical science has been to create a wide variety of single-purpose machines which not only group similar operations and perform them in quantity, but also reproduce skill of hand to a marvellous degree. It is not so much the discovery of new principles as the new combination and application of old ones that mark this development. Under mass production the industry of machine making has increased out of all comparison with its previous history, and the constant designing of new machines is a part of the productive work of every great manufacturing institution.

(4) The effect of mass production on employees has been variously appraised. Whether the modern corporation is the destruction or salvation of arts and crafts, whether it narrows or broadens opportunity, whether it assists or retards the personal development of the worker, must be determined by observable facts. A cardinal principle of mass production is that hard work, in the old physical sense of laborious burden-bearing, is wasteful. The physical load is lifted off men and placed on machines. The recurrent mental load is shifted from men in production to men in designing. As to the contention that machines thus become the masters of men, it may be said the machines have increased men's mastery of their environment, and that a generation which is ceaselessly scrapping its machines exhibits few indications of mechanical subjection.

The need for skilled artisans and creative genius is greater under mass production than without it. In entering the shops of the Ford Motor Company, for example, one passes through great departments of skilled mechanics who are not engaged in production, but in the construction and maintenance of the machinery of production. Details of from 5,000 to 10,000 highly skilled artisans at strategic points throughout the shops were not commonly witnessed in the days preceding mass production. It has been debated whether there is less or more skill as a consequence of mass production. The present writer's opinion is that there is more. The common work of the world has always been done by unskilled labour, but the common work of the world in modern times is not as common as it was formerly. In almost every field of labour more knowledge and responsibility are required than a generation or two ago.

Some Criticisms Answered.—Mass production has also been studied with reference to what has been called the monotony of repetitive work. This monotony does not exist as much in the shops as in the minds of theorists and bookish reformers. There is no form of work without its hardness; but needless hardship has no place in the modern industrial scheme. Mass production lightens work, but increases its repetitive quality. In this it is the opposite of the mediaeval ideal of craftsmanship where the artisan performed every operation, from the preparation of the material to its final form. It is doubtful, however, if the mass of mediaeval toil was as devoid of monotony as has sometimes been pictured, but it is absolutely certain that it was less satisfactory in its re-

sults to the worker. In well-managed modern factories the tendency to monotony is combated by frequent changes of task.

The criticism of mass production as a means of reducing employment has long since been out of court. The experience of the Ford Motor Company is that wherever the number of men has been reduced on manufacturing operations, more jobs have been created. A continuous programme of labour reduction has been paralleled by a continuous increase in employment. As to the effect of mass production on wages and the relations between managers and men, there is little need to speak. It is perhaps the most widely understood fact about mass production that it has resulted in higher wages than any other method of industry. The reason is at hand. The methods of mass production enable the worker to earn more and thus to have more. Moreover, the methods of mass production have thrown so much responsibility on the craftsmanship of management, that the old method of financial adjustment by reduction of wages has been abandoned by scientific manufacturers. A business that must finance by drafts out of the wage envelopes of its employees is not scientifically based. It is the problem of management so to organise production that it will pay the public, the workmen and the concern itself. Management that fails in any of these is poor management. Disturbed labour conditions, poor wages, uncertain profits indicate lapses in management. The craftsmanship of management absorbs the energies of many thousands of men who, without mass production methods, would have no creative opportunity. Here the modern method broadens instead of narrows individual opportunity.

(5) As to the effects of mass production on society, the increasing supply of human needs and the development of new standards of living are the elements to be estimated. The enlargement of leisure, the increase of human contacts, the extension of individual range, are all the result of mass production. (H. Fo.)

See H. Ford, *My Life and Work* (1924), and *To-day and Tomorrow* (1926); E. G. Filene, *The Way Out* (1924); and Articles in the American *Economic Review*.

MASTABA, in Egyptian architecture, a rectangular cut stone tomb, with raking sides and a flat roof, usually containing three chambers. In the first the walls were sometimes richly decorated with paintings and had a low bench of stone on which incense was burnt. The second, containing the *serdab,* or image of the deceased, was either closed, with holes pierced in the wall separating it from the first chamber, or entered through a narrow passage through which the fumes of the incense passed. A vertical well-hole descended to the third in which the mummy was laid.

MASTER, one holding a position of authority, disposition or control over persons or things. As a title of the holder of an office, the use of the Lat. *magister* is very ancient. *Magister equitum,* master of the horse, goes back to the early history of the Roman Republic (*see* DICTATOR). The British office is termed MASTER OF THE HORSE. In mediaeval times the title was of great frequency. In the British royal household most of the offices bearing this title are now obsolete. Of the greater offices, that of master of the buckhounds was abolished by the Civil List Act 1901. The master of the household, master of the ceremonies, master of the king's music still survive. Since 1870 the office of master of the mint has been held by the chancellor of the exchequer. A deputy performs administrative and other duties.

At sea, a "master" is more properly styled "master mariner." In the merchant service he is the commander of a ship, and is by courtesy known as the captain. In the British navy he was the officer entrusted with the navigation under the captain. He had no royal commission, but a warrant from the Navy Board. Very often he had been a merchant captain. His duties are now performed by the staff commander or navigating lieutenant. The master-at-arms is the head of the internal police of a ship; the same title is born by a senior gymnastic instructor in the army. In the United States navy, the master is a commissioned officer below the rank of lieutenant.

"Master" appears as the title of many legal functionaries (for the masters of the supreme court *see* CHANCERY; and KING'S BENCH, COURT OF; for masters in lunacy *see* INSANITY: *Law; see* also MASTER OF THE ROLLS, p. 43). The "master of the faculties" is the chief officer of the archbishop of Canterbury in his court of faculties. His duties are concerned with the appointment of notaries and the granting of special licences of marriage. The duties are performed *ex officio* by the judge of the provincial courts of Canterbury and York, who is also dean of Arches, in accordance with s. 7 of the Public Worship Regulation Act 1874. The "master of the Temple" is the title of the priest-in-charge of the Temple church in London. It was formerly the title of the grand master of the Knights Templars. The priest-in-charge of the Templars' church was properly styled the *custos,* and this was preserved by the Knights Hospitallers when they were granted the property of the Templars at the dissolution of that order. The Act of 1540 (32 Henry VIII.), which dissolved the order of the Hospitallers, wrongly styled the *custos* master of the Temple, and the mistake has been continued. The proper title of a bencher of the Inns of Court is "master of the Bench" (*see* INNS OF COURT). The title of "Master-General of the Ordnance" was revived in 1904 for the head of the Ordnance Department in the British military administration.

"Master" is the ordinary word for a teacher, very generally used in the compound "schoolmaster." The word also is used in a sense transferred from this to express the relation between the founder of a school of religion, philosophy, science, art, etc., and his disciples. It is partly in this sense and partly in that of one whose work serves as a model or type of superlative excellence that such terms as "old masters" are used. In mediaeval universities *magister* was particularly applied to one who had been granted a degree carrying with it the *licentia docendi,* the licence to teach. In English usage this survives in the faculty of arts. The degree is that of *artium magister,* master of arts, abbreviated M.A. In the other faculties the corresponding degree is doctor. Some British universities give a master's degree in surgery, *magister chirurgiae,* C.M. or M.Ch., and also in science, *magister scientiae,* M.Sc.

Master was the usual prefix of address to a man's name, though originally confined to people of some social standing. Probably under the influence of "mistress," it was corrupted in sound to "mister," and was abbreviated to "Mr." In the case of the puisne judges of the High Court "Mr. Justice" is still used as the proper official form of written address. The Speaker of the House of Commons and the Speaker of the House of Representatives at Washington and also the Speakers in the State Legislatures are formally addressed as Mr. Speaker. The President of the United States is always addressed as Mr. President.

MASTER AND SERVANT. This comprehensive term includes all forms of occupation in which a person for valuable consideration hires out his services in a subordinate capacity to another for the purpose of helping that other in the performance of some duty or object for which assistance is either necessary or desirable. The contract need not be reduced into writing unless by the terms of the bargain the employment is to extend beyond a year, in which case, a written agreement is necessary, under s. 4 of the Statute of Frauds (*Dollar* v. *Parkington,* 1901, 84 L.J. 470). Consequently, a contract of service for a period of more than one year, terminable at any time by six months' notice, is unenforceable unless there be a memorandum in writing (*Hanau* v. *Erlich,* 1912, A.C. 39). Nor will part performance take the case out of the statute. It seems, however, that a contract of hiring for a year certain need not be evidenced by writing unless it is to commence at a future date which would extend the term of employment beyond the year. Where the agreement is in writing, the consideration for the servant's promise to remain in the master's employ should appear on the face of the document and also the period during which the hiring is to continue and the length of notice necessary for its termination. But in a general hiring by parol the nature of the employment is a factor to be considered in determining alike the duration of the engagement and the length of notice. In the case of a domestic or menial servant a general hiring will be construed as a hiring for a year terminable by a month's notice or by payment of a month's wages (with nothing additional for board and lodging) on the part of the master, and by a month's notice on the part of the servant. There is, how-

ever, no right of set off by a master for accidental breakage of domestic utensils by a servant. A custom in domestic service that either party may determine it at the end of the first month by notice given at any time during the first fortnight has been held reasonable (*George* v. *Davis,* 1911, 2 K.B. 445). Judicial decisions show that the rule as to a month's notice is not applicable in the case of an editor, a governess, a farm bailiff, a steward, the house-keeper of a large hotel or a servant in husbandry. But it has been held to apply to a gardener and a huntsman.

Where the relation of master and servant clearly exists, the employer is responsible for injury occasioned by the negligent conduct of the servant in carrying out his orders. And this rule is so extensive as to make the master liable for the careless, reckless and wanton conduct of his servant, provided it be within the scope of his employment. But this responsibility does not prevent the servant from also being liable. A master is not, however, responsible for a wilful fraud outside the course of the servant's employment, or for an act inconsistent with the nature of his duties.

If a servant wilfully disobey any lawful order of his master or unlawfully absent himself from his work, or if he be guilty of moral misconduct, or take a concealed commission, or prove grossly incompetent in some particular service for which he was engaged, he may be discharged without notice before the expiration of the period for which he was hired Nor, in such case, is he entitled to any wages from the date of his discharge, if they had not then accrued due. There is no legal obligation on the part of the master to give a "character" to a domestic or menial servant, but it is common law misdemeanour for any one to give a false character either verbally or in writing. A master need not, when dismissing a servant, allege any particular act on the part of the latter as the ground for his discharge, it being sufficient for such cause actually to exist.

The obligations entailed upon a master towards his servant are further enhanced by the provisions of the National Health Insurance Act 1924. The consideration for the benefits under this Act, in the cases to which it applies, being a compulsory weekly payment by the master and the servant of the amounts set out in the second schedule to the act. *See* EMPLOYERS' LIABILITY; LABOUR LAW. (W. W. P.)

MASTER OF THE ROLLS, in England, originally chief of the 12 clerks or masters in chancery and as such keeper of the rolls, especially of the register of original writs, and of all patents and grants under the great seal. He was first called master of the rolls in the statute 11 Hen. VIII. ch. 18. Before and after this date he is sometimes called vice-chancellor, since with the development of the chancery as a court, he was called upon to sit at first with the justices or with two or more masters; later, in the absence of the chancellor, by himself for judicial business. In fact he became the deputy of the chancellor. Meanwhile he had long ceased to be keeper of the records, but by the Public Record Office Act, 1838, their custody was restored to him, and he is now also chairman of the State Papers and Historical Manuscripts Commissions. Under the Judicature Act, 1875, and the Appellate Jurisdiction Act, 1876, he now always sits with the lords justices in the court of appeal (which usually sits in two divisions of three judges, the master of the rolls presiding over one division), whose decisions can be questioned only in the House of Lords. The master of the rolls was formerly eligible to a seat in the House of Commons. Sir John Romilly, appointed in 1851, was the last to enjoy this privilege, which was abolished by the Judicature Act, 1873. The salary is £6,000; the holder is sworn to the Privy Council.

See Holdsworth, *Hist. Eng. Law,* vol. i., ch. v. (H. H. L. B.)

MASTER OSCILLATOR, as applied to radio, is an oscillator of comparatively low power so arranged as to control the frequency of the output of an amplifier.

MASTERS, EDGAR LEE (1869–), American poet and novelist, was born at Garnett, Kan., on Aug. 23, 1869. He entered Knox college in Galesburg, Ill., and was admitted to the bar in 1891. A small book of verses appeared in 1898; followed by *Maximilian,* a drama in blank verse (1902); *The New Star Chamber and Other Essays* (1904); *Blood of the Prophets* (1905); *Althea,* a play (1907); and *The Trifler,* a play (1908).

It was William Marion Reedy, of St. Louis, who, in 1914, advised Masters to deal with the people of his own day, with human nature as he had seen it revealed in the court-room and the attorney's office. Masters produced a series of post-mortems spoken by the erstwhile inhabitants of a Middle-Western village from beyond the grave. He entitled his work *The Spoon River Anthology.* It remains Masters's greatest effort.

Two of Masters's best short poems are to be found in *Songs and Satires* (1916); other volumes of his poetry are. *The Great Valley* (1916); *Toward the Gulf* (1918); *Starved Rock* (1919); *Domesday Book* (1920); and *The New Spoon River* (1924). But the content of these books is most uneven in quality. Masters has also essayed the novel. His novels of boyhood, as *Mitch Miller* (1920), are his best. His novels of maturity, such as *The Nuptial Flight* (1923), *Mirage* (1924), are uneven in workmanship, though they contain some striking ideas. *Lee* (1926) is a long dramatic poem; *Jack Kelso* (1928), in which the central figure is a poet, a wanderer and a friend of Lincoln, is a poem having the proportions of an epic. Masters has been the opponent of hypocrisy and is often an ironist of great power.

See "Edgar Lee Masters: Critic of Life" in Llewellyn Jones's *First Impressions* (1925); "Robert Herrick and Edgar Lee Masters. Interpreters of our Modern World," in Harry Hansen's *Mid-West Portraits* (1923); Amy Lowell on Masters in *Tendencies in Modern American Poetry* (1917) and Louis Untermeyer's comments in *American Poetry since 1900* (1923). (W. R. BE.)

MASTIC or MASTICH, a resinous exudation obtained from the lentisk, *Pistacia Lentiscus,* an evergreen shrub of the family Anacardiaceae. The lentisk or mastic plant is indigenous to the Mediterranean coast region from Syria to Spain, but grows also in Portugal, Morocco and the Canaries. The production of the substance has been, since the time of Dioscorides, almost exclusively confined to the island of Chios. The shrubs are about 6 ft. high. The resin is contained in the bark and not in the wood, and in order to collect it numerous vertical incisions are made, during June, July and August, in the stem and chief branches. The resin speedily exudes and hardens into oval tears, which are collected every fifteen days. The collection is repeated several times between June and September, a fine tree being found to yield about 8 or 10 lb of mastic during the season. Mastic occurs in commerce in the form of roundish tears about the size of peas. They are transparent, with a glassy fracture, of a pale yellow or faint greenish tinge, which darkens slowly with age. Its use in medicine is obsolete, and it is employed for making varnish.

Pistacia Khinjuk and *P. cabulica,* trees growing throughout Sindh, Baluchistan and Cabul, yield a kind of mastic. In Algeria *P. atlantica* yields a solid resin. Cape mastic is the produce of *Euryops multifidus,* the resin bush, or *harpuis bosch* of the Boers —a plant of the Compositae family. Dammar resin is sometimes sold under the name of mastic. The West Indian mastic tree is the *Bursera gummifera* and the Peruvian mastic is *Schinus Molle.* The name mastic tree is also applied to a timber tree, *Sideroxylon Mastichodendron,* family Sapotaceae, which grows in the West Indies and on the coast of Florida.

MASTIGOPHORA, an alternative name for the group *Flagellata* (q.v.) of the Protozoa.

MASTODON, a name given by Cuvier to those early forerunners of the elephants (*q.v.*) which have nipple-like prominences on the molar teeth. The generic term is now restricted by H. F. Osborn to a single species, *Mastodon americanus,* the American mastodon, but it is used familiarly to include a very large number of forms chiefly of Miocene and Pliocene age. For general account of these animals *see* the article PROBOSCIDEA.

The American mastodon is a large elephant which lived during Pleistocene times in the forests of eastern North America. It possesses molar teeth in which the ridges are placed transversely and are almost straight, the valleys between them not being blocked by intermediate cusps. The anterior molar possesses only three ridges. The upper tusks are large, devoid of enamel and upwardly directed, whilst the lower tusks are present only in the young animal as short, straight and forwardly directed spikes.

The ancestry of the American mastodon is unknown, but forms which are apparently closely allied have been discovered in China,

whilst a series of European animals, culminating in *Mastodon borsoni* are usually regarded as related. This association is, however, denied by H. F. Osborn. Skeletons of the mastodon have been found in Ohio and in the Hudson valley; all over the United States, its remains have been recorded, but it is rare in the Middle West and South. It is usually found in the deposits laid down in a swamp or small pool, and it seems certain that the animal was a forest form, living upon trees. (*See* also ELEPHANT, MAMMOTH.)

(D. M. S. W.)

MASTOID: *see* EAR, ANATOMY OF; EAR, NOSE AND THROAT, DISEASES OF.

MASʻŪDĪ (ABŪ-L ḤASAN ʻALĪ IBN ḤUSAIN IBN ʻALĪ UL-MASʻŪDĪ) (d. *c.* 956), Arabian historian, was born at Baghdad towards the close of the 9th century. After he had been in Persia and Kerman, he visited Istakhr in 915, and went in the following year to Mūltān and Manṣūra, thence to Cambay, Saimur and Ceylon, to Madagascar and back to Oman. He visited Tiberias in Palestine, and described the relics of the Christian church there. In 943 he was in Antioch, and two years later in Damascus. The last ten years of his life he spent in Syria and Egypt. Himself a Moʻtazilite (*see* MOHAMMEDAN INSTITUTIONS), he took his information, when necessary, from Persians, Jews, Indians, and even the chronicle of a Christian bishop.

His most extensive work was the *Kitāb akhbār uz-Zamān* or *Annals*, in 30 volumes with a supplement, the *Kitāb ul-Ausaṭ*, a chronological sketch of general history. The substance of the two parts was united by him in the *Murūj udh-Dhahab wa Maʻādin ul-Jawāhir* ("Meadows of Gold and Mines of Precious Stones"), completed in 947 (French translation 9 vols. Paris 1861–77). In 956 he finished a second edition of this. Another work of Masʻūdī, written in the last year of his life, is the *Kitāb ut-Tanbīh wal Ishrāf* (the "Book of Indication and Revision"), in which he summarizes the work of his life and corrects and completes his former writings. It has been edited by M. J. de Goeje (Leiden, 1894).

An account of Masʻūdī's works is to be found in de Sacy's memoir and in Goeje's preface to his edition of the *Tanbīh*, and of the works extant in C. Brockelmann's *Gesch. der Arabischen Litteratur*, i. 144–145 (Weimar, 1898). C. Field's *Tales of the Caliphs* (1909) is based on Masʻūdī.

MASULIPATAM or BANDAR, a seaport of British India, administrative headquarters of the Kistna district of Madras, on one of the mouths of the river Kistna, 215 m. N. of Madras city. Pop. (1931), 56,928. Masulipatam was the earliest English settlement on the Coromandel coast, its importance being due to the fact that it was the *bandar* or port of Golconda. An agency was established there in 1611. During the wars of the Carnatic, the English were temporarily expelled the town, which was held by the French for some years. In 1759 the town and fort were carried by storm by Colonel Forde, an achievement followed by the acquisition of the Northern Circars (*q.v.*). In 1864 a great storm-wave swept over the entire town and is said to have destroyed 30,000 lives. In former days the chintzes of Masulipatam had a great reputation, but the weaving industry has declined. There are cotton ginning and pressing factories and rice mills, and Masulipatam has a college and training schools. The port is only a roadstead, where vessels anchor 5 m. out. There is a branch line from Bezwada on the Madras and Southern Mahratta railway. The chief educational institution is the Noble college of the Church Missionary Society.

MASURIAN LAKES, BATTLES OF THE, 1914 AND 1915. (*See* TANNENBERG.) It was the lake barrier which had proved the undoing of the Russians in their advance into East Prussia, and twice again was it to bring about their defeat when the Germans in their turn assumed the offensive. Jilinsky had failed to combine the action of his two armies, urging one forward to intercept what he thought to be a beaten enemy and dispatching the other on a subsidiary objective. The disaster to the II. Army had come to him as a crushing surprise, and in his fear that Rennenkampf would share the fate of Samsonov, he ordered the I. Army to halt and act on the defensive until fresh troops could be brought up from the centre of Russia. All chance of catching the Germans at a disadvantage during their temporary disorganization after the fighting at Tannenberg was thus lost.

I. THE SUMMER BATTLE

Ludendorff was not long in deciding what was to be done after the destruction of Samsonov. Even before the fighting at Tannenberg was over, on Aug. 29, 1914, he had commenced moving troops northwards to meet Rennenkampf. He was strongly urged to move southwards to the support of the sorely tried Austrians, but this would have meant leaving a strong and undefeated enemy directly in his rear, whilst attempting to traverse the self-same desert area which had tried Samsonov so greatly. From the German point of view it was more important to free East Prussia from the invader at once, and the Austrians must therefore wait their turn.

Position Before the Action.—All the German divisions had received their first reinforcements and were flushed with victory and full confidence in their leaders. Two fresh corps had arrived from the west. Rennenkampf did not appear to be on the move and was evidently commencing the blockade of Königsberg. Lötzen, the little fortress holding the main gap in the centre of the line of lakes, was still in German hands. Everything therefore seemed favourable for a German offensive.

Ludendorff's plan for his advance was in outline as follows: (1) Goltz with 2½ divisions was to check any advance on the part of the Russian II. Army from Poland; (2) François with three divisions and a cavalry brigade was to move round the southern end of the lakes at Johannisburg with the primary object of turning Rennenkampf's left, and at the same time dealing with any Russian forces assembling to the south of the lakes; (3) Mackensen with two divisions and two cavalry divisions was to cross the Lötzen gap and join with François in the attack against Rennenkampf's left; (4) the main body of eight divisions was to move direct on the Insterburg gap; (5) the Königsberg garrison was to make a demonstration against the blockading troops.

Rennenkampf had commenced withdrawing on Aug. 30, and on Sept. 2 he issued orders for a position to be taken up for defensive action from the sea near Libau to Angerburg at the northern end of the lakes. This position offered many advantages from a defensive point of view, running as it did behind the rivers Deime, Alle and Omet, but it was too extensive for the force of 12 divisions which Rennenkampf had at his disposal, the distance from flank to flank being 60 miles. Moreover, the left flank was exposed to attacks coming from the Lötzen gap and the southern end of the lakes. But it was chiefly in the manner in which he proceeded to occupy this position that he erred. He had no idea where the Germans were or what they had been doing in the interval since Tannenberg. He only had persistent rumours that the Germans were sending billeting parties to Königsberg. Instead of maintaining strong forces in front of his chosen position, in order to discover the enemy's intentions, Rennenkampf committed his troops at once to a linear defence of the line. He placed four of his divisions along the Deime on a front of 18 m., while keeping seven divisions to hold the remainder of his line of 42 miles. A single division was placed opposite the Lötzen gap to the east of the lakes.

It will thus be seen that from the very start of their manoeuvre the Germans had succeeded in out-generalling Rennenkampf. On the left of their line they were containing four Russian divisions with garrison troops, equivalent to about a division. In the centre they were opposing eight divisions to seven Russian divisions. On the right they were advancing with no less than five divisions and two cavalry divisions against a single Russian division.

German Attack.—Goltz attacked and took Mława on Sept. 4, and thereafter kept in check any of the units of the Russian II. Army which attempted to advance. By the night of Sept. 5 François was approaching the southern end of the lakes. By the 6th he had taken Johannisburg and Nikolaiken, driving back the few Russian troops opposing him. By the 7th he was through the lakes and had captured Bialla and Arys. The Russian troops opposing him had been hurried up without proper artillery support and were dispersed in disorder. Eleven Russian battalions were thus dissipated without result. On the 8th François turned northwards against the Russian flank. Sept. 9 was to be a fateful day for the Germans. Mackensen had commenced his crossing at Lötzen during the 8th, but he could not enlarge the bridge-head.

His troops attacked at 5 A.M., 12 noon and 8 P.M. on this day without success and that evening he reported no progress to François.

François' attack against Soltmahnen on the morning of the 9th came as a complete surprise to the left flank of the Russians opposing Mackensen. By noon the Russians were in hopeless rout, leaving 5,000 prisoners and 60 guns in the hands of François. The German enveloping movement had met with complete success. Rennenkampf's left flank division had been destroyed and about 8,000 men of the Russian X. Army concentrating about Augustówo and Osowiec had been placed out of action. The left flank of Rennenkampf's army now lay open to the attack of five German divisions. A second Tannenberg seemed more than probable.

Ludendorff had employed the 5th, 6th and 7th in bringing his eight divisions in line facing the Insterburg gap and, on the 8th, contact was gained with Rennenkampf's outposts. On the 9th, coinciding with François' attack, the Germans moved forward along the whole front. Little progress was made anywhere, and on the right the Russians made a determined counter-attack which completely held up the German advance. This check seems to have paralyzed Ludendorff temporarily, for he ordered his right under François and Mackensen to hold fast and even to close in to the centre for fear of disaster. But Rennenkampf had taken fright at the menace to his left and had decided to withdraw. That night he ordered a general retreat. He had been just too quick for the Germans. When Ludendorff allowed his right to move forward again, nothing further than cutting off the streams of disorganized transport and breaking up the Russian rear-guards was possible. Rennenkampf had pushed his retreat with desperation. Two of his corps had covered 58 m. in 60 hours. By the 13th he was safe from annihilation, and by the 14th his exhausted troops had crossed the East Prussian frontier between the forest of Rominten and the river Niemen.

Although the Russian I. Army had not been surrounded, it had suffered almost as much as the II. Army. Casualties since Sept. 6 had amounted to 125,000 men and 150 guns. Two corps had been destroyed and the whole army was out of action as a mobile force through lack of transport. The chief credit for this success must lie with François. In his march round the southern end of the lakes his men had covered 77 m. in the four critical days Sept. 6–9, and there had been severe fighting on two of those days. Had Ludendorff been quicker to realise that Rennenkampf's counter-attack on the 9th was made in order to disengage himself, and had his orders to François for the 10th and 11th not been so cautious, there can be no doubt that Rennenkampf's army would have been all but destroyed.

II. THE WINTER BATTLE

During their 28 days' invasion of East Prussia the Russians had lost some 310,000 men from the flower of their army and 650 guns. Their offensive had been completely defeated and they had been thrown on the defensive. It was not till late in the winter of 1914–15 that they began to show signs of activity once more. From the German point of view it was important to prevent another Russian invasion of East Prussia and it was therefore decided to upset the Russian plans by a strong offensive.

German Dispositions.—In Jan. 1915 the German VIII. Army, under Below, was holding a line from the frontier south of Lake Spirding, to the river Memel. Some 100,000 Germans were facing 200,000 men of the Russian X. Army under Siewers. To the south there were signs of a Russian XII. Army being assembled between Modlin and Thorn. Four fresh corps had been allotted for the offensive, making a total of some 250,000 men. In outline the German plan was as follows: (1) The X. Army (eight divisions and one cavalry division), under Eichhorn, was to envelop the Russian right, moving southwards from the Insterburg gap. (2) The right wing of the VIII. Army (three divisions), under Litzmann, was to envelop the Russian left by moving round the southern end of the lakes. (3) The remainder of the VIII. Army (four divisions) was to hold the centre.

Orders for the advance were issued on Jan. 28. The attack in the south was to commence on Feb. 7, with a view to drawing the attention of the Russians to this quarter. The main attack was then to come from the north on the 8th. Conditions were very different from those of the advance in Sept. of the year before. The weather was bitterly cold and the whole country was deep in snow. Large numbers of sleighs had been collected and the scale of clothing and food greatly increased. The German administration left nothing undone which could be thought out beforehand.

German Line Advanced.—Litzmann's advance found the marshy country in front of Johannisburg almost impassable, and the attack of the 7th came to little. Many of the units had to force their way through blinding snow storms, and it was not till the 8th that the Russian positions on the Pisseck were reached and taken, and by the 9th the end of the lakes was passed. This diversion served its purpose well, for the attack of the German X. Army in the north came as a complete surprise to the Russians in their winter quarters, leisurely thinking of an advance in the spring. They were given no time in which to readjust their line, and reserves had to be thrown in piece-meal to save the situation. On the 10th, a determined stand was made by four Russian divisions on either side of Eydtkuhnen, but by evening their resistance had been broken. Everywhere the effect of the German heavy artillery was decisive. Despite the difficulty of bringing forward the heavy wheeled vehicles, which broke through the frozen crust of the ground, the Germans never failed to support their infantry at the decisive point. By the 12th, Below's army had reached a line stretching from the forest of Rominten to Ludwinow.

Meanwhile, the German centre had moved forward to keep in touch with the southern wing. Russian resistance in the south seemed to centre round the town of Lyck, and Litzmann was reinforced by a fourth division for its capture. From the 10th to the 13th the fighting round Lyck was desperate. Often the opposing sides could not distinguish each other in the blizzards which swept over them, and owing to the difficulty of ammunition supply the infantry were unsupported by artillery fire of any sort, and fierce hand to hand fighting ensued. Casualties on both sides were therefore heavy and the Russians also lost over 8,000 prisoners and 14 guns. By the night of the 13th the Russians had been forced back and the town was in German hands.

Position After the Battle.—By the 14th, the German line ran from Rajgród in the south, through Suwalki, to Sztabinki in the north, in a semi-circle round Augustówo, at a distance of from 9 to 10 m., from the town. The wooded and close nature of the country made concerted attacks very difficult, but everywhere the superior individual training of the German soldier triumphed over the more ignorant Russian. The Russians fought with desperation to maintain their positions and it was not till the 17th that Siewers finally gave the order to abandon Augustówo. He succeeded in escaping envelopment by abandoning most of his transport and ammunition columns and retiring in disorder on Grodno. By the 20th the Germans were no longer in touch with the retreating Russians.

In the winter battle the Russians lost 110,000 prisoners and 300 guns, and the X. Army, like the I. and II. Armies, was placed *hors de combat*. They had been caught unawares in winter quarters, without proper protection and with an inferior intelligence service. Had the Germans been able to bring up the whole of their guns and ammunition on Feb. 14 they might have succeeded in surrounding Augustów, but the weather prevented this.

Bibliography.—H. von Redern, *Winterschlacht in Masuren* (1918); P. von Hindenburg, *Out of My Life* (1920); E. Ludendorff, *My War Memories* (1922); Hoffmann, *The War of Lost Opportunities*, London, 1924. Camon, *Ludendorff sur le Front Russe, 1914–15*, Paris, 1926. (*See* also World War: *Bibliography*.) (W. E. I.)

MASURIUM or **EKA-MANGANESE**, a chemical element, atomic number 43, the existence of which has only been demonstrated spectroscopically (*see* [Frl.] J. Tacke, *Zeit. angew. Chemie*, 1925).

MATABELE ("vanishing" or "hidden" people, so called from their appearance in battle, hidden behind enormous oxhide shields), a people of Zulu origin, who under the chief Mosilikatze were driven out of the Transvaal by the Boers in 1837. In their new territories the Matabele absorbed many members of the conquered Mashona tribes. The Matabele are now herdsmen and

agriculturists. The sororate is practised and a man may marry all his wife's sisters. (See *Africa*, vol. i., no. 4 [1928].)

MATACAN, an independent linguistic stock of South American Indians, so called from the Matacos, its best-known tribe. The Matacan tribes occupied a considerable area in the Bolivian and Argentine Chaco, along the Pilcomayo and Vermejo rivers, from the foothills of the Andes eastward to the Paraguay. Many of the tribes belonging to the stock are now extinct. The Matacos to-day are found south of the Vermejo in the western Chaco. The Chorotes (*q.v.*), one of the tribes of this stock, have recently been carefully studied by Nordenskiold. As described by the older writers, the Matacos (Mataguayes) and their affiliated tribes were an ugly, dark-skinned people, living mainly by hunting and fishing. They wore a kilt of skins, and lived in temporary small grass-thatched huts with very small, low doorways like those of the Chiquitos (*q.v.*). Their weapons were the bow, spear and club. They appear to have had no chiefs or leaders of authority. Monogamy was the rule. They performed elaborately costumed dances, but had no religious structures or images.

See D. G. Brinton, "Linguistic Cartography of the Chaco Region" (*Proc. Amer. Philos. Soc.*, vol. xxxvii.); J. Cardus, *Las Missiones Franciscanas en el territorio de la Republica de Bolivia* (Barcelona, 1886).

MATACHINES, bands of mummers or itinerant players in Mexico, especially popular around the Río Grande, who wander from village to village during Lent, playing in rough-and-ready style a set drama based on the history of Montezuma. Dressed in fantastic Indian costumes and carrying rattles as their orchestra, and with the help of a chorus of dancers they portray the desertion of his people by Montezuma, the luring of him back by the wiles and smiles of Malinche, the final reunion of king and people, and the killing of *El Toro* (the bull), the author of all the mischief.

MATADOR: *see* BULL-FIGHTING.

MATAGALPA, the metropolis of the coffee region of Nicaragua, a highland town with a number of foreign residents. The town lies about 3,000 ft. above the sea, has a population (1928) of about 12,000, and during the dry season is reached in a few hours from Managua by motor car (distance, 103 m.) and in the wet season, from Managua and León (120 m.) by mule or horseback, a two-day journey at its best. The coffee is shipped via Corinto. Matagalpa is a base for the mining and timber-cutting areas.

MATAMOROS, a town and port of the State of Tamaulipas, Mexico, on the south bank of the Río Grande, 28 m. from its mouth, opposite Brownsville, Texas. Pop. (1910) 7,390. Matamoros stands in an open plain, the commercial centre for a large district, but its import trade is prejudiced by the bar at the mouth of the Río Grande, which permits the entrance of small vessels only. The exports include hides, wool and live stock. The importance of the town is due to Brownsville, Texas, across the border, and its rail connection southward into Mexico. Matamoros was founded early in the 19th century, and was named in honour of the Mexican patriot Mariano Matamoros (*c.* 1770–1814). In the war between the United States and Mexico, Matamoros was easily taken by the Americans on May 18, 1846, following Gen. Zachary Taylor's victories at Palo Alto and Resaca de la Palma. Matamoros was occupied by the Mexican imperialists under Mejía in 1864, and by the French in 1866.

MATANZAS, an important city, port and centre of the sugar industry of Cuba, located on the northern coast of the island, 58 m. E. of Havana. Pop. (1931) 68,772. It is reached by rail, electric line, and by the new Central highway, from Havana and is connected by rail and highway with Santiago (481 m. S.E.). The harbour is in an open bay, 2 m. wide. Three rivers flow into the bay. Of these rivers the Yumuri is famous for the beauty of its valley, back of the city. Matanzas is divided into three sections by the Yumuri and the San Juan rivers. Wooded hills rise above the sloping plain on which the city is built, and above them the conical Pan (or loaf) de Matanzas (1,277 ft. high) which is a notable landmark. The Paseo de Martí, skirting the harbour, is a famous drive, marked at one end by a statue of Ferdinand VII. of Spain and on the other by a monument to the heroes of Cuban independence executed here by the Spaniards. A drive leads also to the ancient Castillo de San Severino (built in 1694 and rebuilt in 1773), to two more modern forts and to the Yumuri valley and the Caves of Bellamar, famous resorts. In the Yumuri valley is the Hermitage of Monteserrata, on La Cumbre, a hill crowning the valley. The history of Matanzas antedates the founding of the city, which took place in 1693, for prior to that its harbour was the resort of pirates. The town received the right to local government in 1694, and in 1815 was made capital of its department. Gabriel de la Concepción Valdés, a mulatto poet known as El Plácido (1809–1844), was born in Matanzas and executed there for participation in the negro conspiracy of 1844.

MATARÓ (anc. *Iluro*), a seaport of north-eastern Spain, in the province of Barcelona, on the Mediterranean Sea and the Barcelona-Perpignan railway. Pop. (1930), 28,114. The wine of the neighbourhood, which resembles port, is shipped in large quantities from Barcelona; and the district furnishes fine roses and strawberries for the Barcelona market. The industries include the manufacture of linen and cotton goods, especially canvas and tarpaulin, and of soap, paper, and chemicals. The railway opened in 1848 was the first constructed in Spain. Outside the town is the much-frequented carbonated mineral spring of Argentona.

MATCH. A piece of inflammable material, such as wood, cardboard or waxed thread, provided with a tip which ignites by friction. From the very earliest ages some means of bringing fire into existence has been of primary importance. During the evolution of fire-producers, other methods than that of friction—both chemical and mechanical—have been employed but the most successful agency for obtaining fire has been the friction match.

Discovery of Phosphorus.—In 1670 the alchemist Brand, of Hamburg, discovered phosphorus, which is present in urine in the form of alkaline and organic phosphates. Brand was preparing a liquid from urine which was supposed to possess the power of transmuting silver into gold, and hit upon phosphorus by accident. Phosphorus unites with oxygen with such facility that spontaneous ignition ensues on exposure to air; and the enigma to which early efforts to utilize this material in a practical form were directed, was the control of this property. The earliest known method consisted in the rubbing of a small particle of phosphorus between two pieces of brown paper, and in the igniting of a *"Spunk"* or splinter of wood, previously tipped with sulphur. The risk of injury from burns by this process is apparent, and probably for this reason the employment of phosphorus for the purpose of ignition remained dormant for more than 100 years afterwards. Then the use of the phosphoric taper was suggested. This device consisted of a sealed glass tube containing a small portion of phosphorus, and a small length of waxed thread; ignition occurring upon contact with the atmosphere.

The Phosphorus Bottle of Cagniard de Latour (1810) contained partially oxidized phosphorus used in conjunction with a sulphur tipped splint and ignited by friction. In 1816 François Derosne is stated to have manufactured friction matches containing phosphorus.

Lucifers.—The year 1827 saw the first really useful friction match, made by an Englishman—John Walker, a druggist of Stockton-on-Tees. Walker's matches contained no phosphorus, but were made of chlorate-of-potash, sugar and gum arabic. The method of striking to obtain fire was to draw the splinter of wood, tipped with this composition, rapidly and under considerable pressure, through a piece of folded sandpaper. Imitations of Walker's match were sold by Samuel Jones of London, and also by G. F. Watts under the name of *"Lucifers."* None of these so-called *"Lucifers"* were easy of ignition. Attempts were made to provide special striking surfaces on the box; one of the first being composed of chlorate-of-potash, antimony sulphide, oxide of lead, sulphur and gum arabic, sold under the name of *"Congreves."*

Sauria's Invention.—Notwithstanding these experiments, an easily inflammable friction match was not achieved until a satisfactory method of embodying phosphorus in a suitable mixture was invented. This seems to have been successfully accomplished by Dr. Charles Sauria of St. Lothair in 1831. Sauria neglected

to acquire a patent, and as a consequence matches were manufactured according to his formula in many places, notably in Vienna and Darmstadt.

The Early Dangerous Trade.—The early strike-anywhere matches consisted mostly of a mixture of glue and the inflammable element in large quantities, but as manufacture progressed it was found that a very much smaller quantity of phosphorus was required to arrive at a satisfactory result, and that about 5% in a mixture with chlorate-of-potash and certain inert diluents was sufficient. Unfortunately the use of yellow phosphorus was accompanied by an insidious disease, known as *Phosphorus Necrosis*, or caries of the upper or lower jaw, which attacked workers in the industry, particularly those who were unhealthy. Sesquisulphide of phosphorus can be used without any deleterious effects and has now supplanted the poisonous phosphorus throughout the civilized world; an international convention at Berne in 1906 agreed to prohibit the use of yellow phosphorus.

The Safety Match.—A history of the evolution of the friction match would not be complete without some reference to the safety match, which is manufactured on a somewhat different principle. In this match the oxidizing agent, chlorate-of-potash, is separated from the inflammable portions of the composition, the former being on the head of the match, while the latter, consisting chiefly of amorphous phosphorus, is affixed to the box side.

Match Manufacture.—Since about 1900, the methods of match-manufacture have undergone a complete change. From an industry in which practically every operation was conducted and completed by manual labour, it has become one of the most highly mechanized forms of industry. At the time of the introduction of Walker's Match, "*Spunks*" or splinters of wood were chopped off the wood-block in single units, and were dipped in the same manner. This procedure has now given place to specialized machinery adapted to each and every stage of the manufacture. Modern matches are prepared from two species of wood: viz.:—American pine and aspen.

Probably the earliest effort to provide a speedier means of dipping the matches consisted in assembling the splints in serried rows in a frame, in which each unit was separated. After dipping the matches were then dried, assembled from the frame, and put into the boxes by female labour. The boxes were prepared by cutting a thin shaving from a piece of timber, previously sawn to the correct size and stamped by means of a die folding; then finally fastened down with flour paste, and paper.

Match Machines.—In the modern match factory, ingenious mechanical devices are adapted to each process; in many instances the operations are combined on a single machine, notably on the so-called continuous match machine. There are two preparatory and essential requisites in the manufacture of matches, viz.:—(a) The preparation of the match splint. (b) The putting together of the boxes. In order to prepare the splint, a log with the bark still attached, about 8 ft. or more in length by about 10″ or more in diameter, is crosscut to obtain convenient lengths for subsequent handling. A machine of a simple type is next brought into operation for the purpose of debarking the log. A vertically rotating disc, furnished on its face with several knives set slightly in advance, serves to expose the wood and leaves it free for further treatment, which consists in slitting the log into a thin veneer about $\frac{1}{10}$″ diameter. In this process in England the log is fixed between two dogs, or clutches, of the machine, which seize it at each end and hold it firmly enough to prevent its slipping, while the shaving or veneer is being discharged. A revolving motion is then imparted to it, during which the log is incessantly pressed against a stationary knife. By this means the veneer is formed in one long shaving, suitable for further treatment in a crosscutter, which descends upon the assembled veneer. The output of this splint cutting contrivance approaches 2 millions per hour.

Impregnation of the splints in a chemical solution to prevent a glowing ember comes next, and for this purpose boric acid can be used. Splints are then dried and finally cleaned and straightened for presentation to the continuous match machine.

Box-making.—The making of the boxes follows up to a point the same route as the preparation of the splints, but with certain differences. The shaving is cut thinner, being only about 1/30″ thick, and the veneering machine for this purpose is fitted with scoring knives, which serve to mark the shaving in the exact place for the convenience of subsequent folding. The assembled veneer is then submitted to the chopper and sliced into its necessary widths. A complete box is composed of three distinct pieces of wood: (a) The rim of the inside, (b) The bottom of the inside, (c) The outer case. There are two machines for the preparation of the box, the inner machine and the outer; both are automatic. A machine for making the outsides can turn out 8,000 to 10,000 boxes per hour, while the inside machine can make 6,000 to 7,000 per hour.

The Continuous Match Machine.—On being assembled, the boxes are then carried forward to the continuous match machine. There are types, with varying capacity, but in round figures 7½ millions of matches can be paraffined, dipped, dried and put into their final resting-place in the space of 10 hours by one of these wonderful machines, with the assistance of about four attendants. In area, one type occupies a space of about 53 ft. long by 10 ft. wide by 9 ft. high. It weighs over 20 tons. For the purpose of obtaining a good mental picture of one of these machines, an endless perforated steel plate of considerable length can be readily imagined, at the beginning of which the splints contained in a suitable hopper are inserted by a joggling mechanism and a plunger into the plate, are carried forward over and dipped into the heated paraffin, and thence forward to a container with the striking composition, where they receive the ignitive head. A further advance carries them over and under a series of planes, during which the drying is completed, which process occupies about one hour of time, until they arrive almost at the point from which they started, when they are ejected into the boxes, the inner of which has been previously placed into the outer by an apparatus specially designed for this purpose. The continuous machine then opens the empty box by a self-acting plunger, and closing it again in a similar manner, delivers it ready for the wrapping operation.

(W. H. Di.)

UNITED STATES

The process of matchmaking in the United States differs radically from that common in England. The planks for the matches are sawed 2 in. thick, seasoned for two years, and then sawed into match blocks, of which those free from knots and with a straight grain are selected to be cured and fed into the match machine. At the head of the match machine, which is about 50 or 60 ft. long and 20 ft. high, is a frame which holds rows of hollow dies, which descend vertically and cut out splints from the match blocks. Some machines cut 50 splints at each revolution, and, with a speed of over 300 revolutions a minute, have produced 10,000,000 matches in a working day. Square stick matches are not popular in America and their manufacture is virtually discontinued. Of all wood matches made in the United States 97½% are of round grooved splint type—both strike-anywhere safety and strike-on-box safety types. These splints are automatically forced out of the dies into the perforations of a cast-iron plate. This forms part of an endless chain on which the splints are passed through a chemical solution, containing mono-ammonium phosphate, which impregnates the wood and prevents an afterglow when the match is burned. After drying to evaporate the water from this chemical bath, the machine carries the splints through a bath of paraffin wax, or similar material, so that they will catch fire readily when the match is lighted, the wax taking the place of the sulphur formerly used.

The machine then carries the splints through two dips to put the head on the match. The first dip gives the match the bulb, which is inert to ordinary friction and protects the tip of the match. The second dip forms the eye of the match, which is much smaller than the bulb and ignites when the match is struck. The modern match head contains a large number of chemicals and other ingredients, such as phosphorus, chlorate, potash, zinc oxide, glue and forms of gums, ground glass, quartz, whiting, etc., which must be thoroughly compounded for several hours in large mills

by means of special machines and under expert supervision. After being tipped the matches travel through blasts of air where they are dried. On their return to the head of the machine, punches drive the sticks out of the plates into a mechanism that packs the matches in cardboard boxes in two layers, with the heads in the opposite direction. Strips of cardboard are put over the matches and the covers sealed on the boxes—all by machinery. The book matches, which are supplied to smokers to be carried in the pocket, are safety matches, and are also made automatically by a machine which slits and dips the cardboard, puts the composition on the cover, and binds and cuts apart the books.

MATCH-LOCK: *see* GUN.

MATÉ or PARAGUAY TEA, the dried leaves of *Ilex paraguariensis* (and some other species), an evergreen shrub or small tree belonging to the same genus as the common holly. The leaves are from 6 to 8 in. long, shortly stalked, with a somewhat acute tip and finely toothed at the margin. The small white flowers grow in forked clusters in the axils of the leaves; the sepals, petals and stamens are four in number, or occasionally five; and the berry is 4-seeded. The plant grows abundantly in Paraguay, and the south of Brazil, forming woods called *yerbales*.

Although maté appears to have been used from time immemorial by the Indians, the Jesuits were the first to attempt its cultivation. This was begun at their branch missions in Paraguay and the province of Rio Grande de San Pedro, where some plantations still exist, and yield the best tea that is made. From this circumstance the names Jesuits' tea, tea of the Missions, St. Bartholomew's tea, etc., are sometimes applied to maté. Under cultivation the quality of the tea improves, but the plant remains a small shrub with numerous stems, instead of forming, as in the wild state, a tree with a rounded head. From cultivated plants the leaves are gathered every two or three years, that interval being necessary for restoration to vigorous growth.

The collection of maté is chiefly effected by Indians employed for that purpose by merchants, who pay a money consideration to the government for the privilege. The Indians usually travel in companies of about twenty-five in number, build wigwams and settle down to the work for about six months. Their first operation is to prepare an open space, called a *tatacua,* about 6 ft. square, in which the surface of the soil is beaten hard and smooth with mallets. The leafy branches of the maté are then cut down and placed on the tatacua, where they undergo a preliminary roasting from a fire kindled around it. An arch of poles, or of hurdles, is then erected above it, on which the maté is placed, a fire being lighted underneath. After drying, the leaves are reduced to coarse powder in mortars formed of pits in the earth well rammed. Maté so prepared is called *caa gazu* or *yerva do polos,* and is chiefly used in Brazil. In Paraguay and the vicinity of Parana in the Argentine Republic, the leaves are deprived of the midrib before roasting; this is called *caa-miri.* A very superior quality, or *caa-cuys,* is also prepared in Paraguay from the scarcely expanded buds. Another method of drying maté has been adopted, the leaves being heated in large cast-iron pans set in brickwork, in the same way that tea is dried in China.

The tea is prepared in a small silver-mounted calabash, the tapering end of which serves for a handle. In the top, there is a hole and the tea is sucked by means of a bombilla. This instrument consists of a small tube 6 or 7 in. long, formed either of metal or a reed, which has at one end a bulb made either of extremely fine basketwork or of metal perforated with minute holes, so as to prevent the particles of the tea-leaves from being drawn up into the mouth. Some sugar and a little hot water are first placed in the gourd, the yerba is then added, and finally the vessel is filled to the brim with boiling water, or milk previously heated by a spirit lamp. A little burnt sugar or lemon juice is sometimes added instead of milk. Maté, like tea and coffee, contains caffeine, but in less quantity. It is also less astringent. Maté retains its flavour against exposure to the air and damp.

See *Kew Bulletin* (1892), p. 132.

MATERA, a city of Basilicata, Italy, capital of the province of Matera, 17 m. S. of Altamura (which is 30 m. W. of Bari) by rail; the line goes on to Miglionico, 18 m. S.W., 1,312 ft. above sea-level. Pop. (1931) 20,243. Part of it is built on a level plateau and part in deep valleys adjoining. The western façade of the cathedral is plain and the south front facing the piazza richly decorated. The campanile is 175 ft. high. In the vicinity are caves with 13th-century frescoes. The district was well populated in the palaeolithic and neolithic periods, and important discoveries have been made by Domenico Ridola.

MATERIAL CULTURE. Even under civilized conditions a great part of man's material culture is directly associated with his primary need, that of procuring food, and his progress in many other directions depends upon the measure of his success in this. The old classification of peoples or communities as hunters, herders or tillers of the soil, is therefore not without value, though it lays undue stress upon this aspect of human life, and more than one question is begged when it is assumed that the higher cultures must have passed through the lower stages to reach their present level. It is quite probable that the first men to begin the cultivation of plants were neither hunters nor herders in a specialized sense, but food-gatherers who, from depending upon such plant and animal produce as they could collect, were led to discover that roots and shoots and seeds could be made productive under control. Apart from those existing backward peoples who live by collecting, hunting and fishing alone, hunting may be a more or less essential activity in higher grades of culture, its importance decreasing with the extension of plant and animal cultivation, until in the higher civilizations it degenerates into a sport. The domestication of animals is, as is well known, often associated with agriculture, though in its intensive form it may have had its first big developments amongst nomadic peoples. The three categories may be regarded as specializations which arose out of the food-gathering that was in the beginning the compulsory occupation of the human stock, as it is of the existing apes. Specialization in, and dependence upon, hunting or the rearing of animal stock, involved a mode of life less likely to lead to and foster plant-growing than would a more settled existence in an area where vegetable food was plentiful, and where the phenomena of growth could be observed under similar conditions year after year. As is generally recognized, a settled life would also provide favourable conditions and incentives for the initiation of other peaceful arts, such as basket- and pottery-making, spinning and weaving; but it was only when plant cultivation established itself as cereal culture—the growing of grain such as barley and wheat, which could be stored for winter consumption—that the first civilizations became possible.

If food is the primary need of man, clothing and shelter, however they first arose, assumed the form of needs partly under stress of climate. Means of travel and transportation, especially over water, were accessory to the more immediate material aims, since they played an important part in opening up new food-areas, and provided new natural products and new environmental stimuli.

Arts and Crafts.—A close study of the means of procuring food leads to the consideration of the innumerable weapons and devices for hunting and fishing; of methods and appliances used in plant cultivation and the tending of domesticated animals; and of the great variety of methods, implements and utensils for carrying, storing and preparing food. With clothing are associated skin-dressing, bark-cloth making, spinning and weaving, whilst in shelter and in travel and transport are involved the building of wind-screens and dwellings, and the construction of carrying devices and water-craft. To the implements and appliances needed for the carrying out of operations connected with all these activities there must be added—with considerable overlap—the tools and mechanisms used in the treatment of materials, and in the construction of artefacts of all kinds.

Many artefacts have their main significance outside the limits of material culture, as, for example, in the case of personal ornaments, instruments for measuring time and weight, musical instruments, religious buildings and images of gods; but as artefacts or inventions these claim consideration from the same point of view as others serving more material ends. Their nature is, indeed, determined by the state of culture with which they are associated, and in their development they may react conspicuously upon the

technique or constructional principles upon which they depend. It is clear that man, even savage man, has aspirations besides those of preserving his life and making himself comfortable, and these carry him far beyond the limits to which he is pushed by necessity.

The ethnologist, in his studies of the culture of an alien people, finds the investigation of the material side of their life less difficult, and more reliable in its results, than is that of the social and religious aspects. There is less risk of error in describing a canoe or a method of making pottery, than in giving an account of a social or religious custom or belief. In the material object or the method the greater part of the truth is on the surface, and is easily grasped. The custom or belief may present features which are utterly foreign to the mode of thought of the investigator, and its real significance exists in the minds of men who may be incapable of explaining it clearly, or who may not desire to do so. Material culture is in fact a study of greater certainty because the evidences are stable and material, and can often be collected for detailed and leisured study. The fact that many artefacts are capable of preservation for hundreds or thousands of years adds to the scope of a study which thus ranges not only wide in space but deep in time.

Upon our accumulated knowledge of the material activities of peoples of all grades of culture a science of comparative technology has been built up which deals in detailed fashion with the technique of arts and crafts. Basket-work (*see* BASKET), pottery (*q.v.*), dwellings, weapons, weaving (*q.v.*) and other subjects are treated from this point of view elsewhere in this section, and only a few general considerations need be touched upon here.

Implements.—Even with some knowledge of natural materials, processes and forces, man can do little with his hands alone; but very much more can be achieved with the aid of a smooth pebble, a pointed stick and a sharp flint (*see* FLINTS). It was in the working of hard materials such as stone, wood and bone, that the hands had to admit their primary incapacity, though there were other things they could not do unaided. In some cases, however, an elaboration of tools and appliances can only increase speed and precision, though even a simple appliance like the primitive plough may produce results which are out of all proportion to its own structural complexity. In the development of most arts and crafts there has necessarily been constant interaction between materials, methods and appliances, but there is no common formula to express the degree of interdependence. Seeds may be sown, and clay may be shaped with little or no assistance from artefacts, but for breaking and crushing hard materials, for cutting, piercing, abrading and similar operations, tools are essential. Simple devices involving the application of leverage, the elasticity of wood and especially rotary motion—as in the drill, the wheel and the rotary quern—pointed the way to the development of machinery as we know it; progress in this direction was, however, dependent not only upon increased knowledge of natural forces and mechanical principles, but upon the production of iron in large quantities, and upon the evolution of methods of working and shaping the metal.

That there are conspicuous differences in the parts played by methods and appliances, respectively, in various arts and crafts, needs little demonstration, and in some cases there has been a great development in appliances without an equivalent improvement in the products. Basket-work, which reaches its highest level amongst uncivilized peoples, requires the simplest of tools, or even none at all, and the forms and fabrics are such as to preclude the use of mechanisms or machines; development has resulted from change and improvement in technique, and not from the invention of artificial aids for the craftsman. Similarly, though not equally, pottery-making was for long an art in which the hand was the only important tool employed in shaping the clay, and the early potter's wheel did not bring about a fundamental change in this respect—discoveries of new kinds of clay, and of better methods of preparing them, and of firing the pots, have been the most important factors in the evolution of pottery. Appliances have, however, played a greater part in the advances that have been made, than in the case of basket-making: In plant cultivation, again, much could be done with the hoe, or even with the simple digging-stick, but the evolution of the plough and of other accessory appliances, was essential to the growth of agriculture to its full usefulness In modern spinning and weaving complex machinery does rapidly and surely what for some thousands of years was done slowly but adequately—as it is still done in some parts of the world—by means of spindles and simple looms made of a few sticks and wooden slats.

Theories of Development.—Since evolution became a dominant motive in scientific studies, the descriptive and comparative methods of treatment have been extended for reconstructive purposes. In anthropology this tendency has been encouraged by the stimulus afforded by the discoveries of the archaeologist, which give us clues not only as to the general course of evolution of material culture, and of individual appliances, but as to the relationships between ancient peoples. That there have been since early days in the history of man, innumerable instances of contact, migration and conquest, and that such relationships have led to transmissions of culture, or of cultural elements, from place to place and from people to people, is generally agreed. The attempts to ascertain how far an existing culture in any part of the world can be resolved into its historical elements—how far stratification can be detected, and transmissions be traced to their sources—have necessarily been based on analyses which take into account not material culture alone, but linguistic, religious, social and physical characters. Reconstructive work of this kind, though sometimes one sided, is the only approach to a scientific history of mankind, as distinct from literary histories of nations and peoples.

The attempted reconstructions are based on views which in their most definite form are regarded as characterizing the historical or diffusionist school of anthropologists. In controversial opposition are those to whom the term "evolutionists" has unaccountably become attached. Whilst the extreme diffusionist regards the independent origin and development of similar or identical methods, artefacts, beliefs and customs, as having been so infrequent as to be of negligible significance, the extreme evolutionist is supposed to postulate independent evolution as an ever-ready explanation of such similarities. It is not probable, however, that there is any evolutionist who denies the occurrence of diffusion, and there is certainly no diffusionist who denies the occurrence of evolution. There is, too, the belief that the whole controversy is futile.

The test question is that of the cultures of the Indians of America. There are some anthropologists who are prepared to regard diffusion as an acceptable and far-reaching explanation within the limits of the Old World and the New, respectively, but who look upon the culture of the American Indians as to all intents and purposes indigenous. This view involves the acceptance of a great number of difficult cases of independent origin and parallel or converging development.

Directional Invention.—In this enquiry much depends on whether we regard man's inventive powers as originative in character, based upon a far-seeing anticipation of ways and means as well as ends, or as an opportunism which ranges from the casual to the persistent according to circumstances. Under modern civilized conditions there is a constant striving, on the part of a small number of individuals, after discovery and invention. Even when the unexpected happens and is seized upon, there is some end in view, though it may be different from that eventually achieved. The world-wide literature of science, modern knowledge of the properties of materials, and of chemical and physical forces, combined with the possession of a great variety of tools and machines, are apt to lead us to conceive of the inventor as a creator rather than an adapter and improviser. Giant strides are apparently made, but they are in reality due to the summation of a number of much smaller steps; judgment is often confused, also, by the fact that a simple discovery may have important results, the discovery being judged by its consequences, and not by its own intrinsic simplicity. The fact that, as is the case with most modern advances, it could not have been made without elaborate apparatus or refined technique, may be of historical

interest, but this does not take it out of the category of the discoveries that man has been making since his career began. In short, the existing social and material conditions enable the civilized inventor to place himself in the way of receiving suggestions that can only reach him by way of methods and appliances that are themselves the end-results of a prolonged process of gradual evolution. Civilized man has, moreover, become convinced that nearly all things are possible, and that the unknown is not only a territory to be explored without fear, but with hope of great reward. He is an opportunist, pursuing discovery and invention by way of experiment to the furthering of directional aims, and his advantages over his early predecessors are due to his social and material heritage, and not to intellectual superiority. We can scarcely doubt that under conditions that favoured the accumulation of knowledge, and that provided opportunities and incentives to the discoverer and inventor, there have been in all the higher human cultures, individuals, relatively few in number, who have adopted such directional methods as their knowledge and material equipment allowed. But the ancient civilizations were themselves based upon the prior evolution of a grade of culture that rendered their foundation possible, and only when these had become well established were the conditions for the emergence of directional invention fulfilled. Even then the limitations of knowledge and the inhibitions of habit, prejudice and superstition, made progress incomparably slower than it is in our own times. Amongst uncivilized peoples, perceptible advance has probably been made only when racial contacts and impacts, great changes in environment, or discoveries which opened up new possibilities—such as those which led to agriculture and metal-working respectively—raised men out of the stagnation due to unchanging environment and a static condition of knowledge. There was new material to work upon, and attempts to apply the old methods were met by unexpected reactions on the part of the material or appliances used.

Chance Discoveries.—If we regard directional invention as characteristic of peoples living under civilized conditions, it is necessary to enquire how progress was made before civilization was established. If it could be said in 1927 that "most discoveries in physics arise from some experimental fact discovered more or less accidentally" (Presidential address [by Sir James B. Henderson] to the engineering section of the British Association for the Advancement of Science, 1927), it is not unreasonable to ascribe to chance the discoveries of early man. It can hardly be supposed that he experimented with stones in order to produce fire, before he had observed the production of sparks by a chance percussion; or that he took to testing the germinating power of seeds, because he felt the need of a more reliable food-supply; nor did he invent the blow-tube because he wanted something with which to shoot pellets or darts. He discovered accidentally that certain results followed certain actions, and in many cases the means came to hand and the end was achieved before the need was realized. There must have been innumerable instances of failure to recognize that a useful discovery was within reach, and the means and the end and the need alike remained unknown. Clay may have hardened in the fire, and copper melted, many times in vain.

It may be said that a manner of progress such as this, may account for the primary discoveries of man, and for their application in simple methods and appliances, but that he must have soon got beyond this dependence upon environmental suggestion; and indeed there was a gradually increasing change in the conditions determining the nature of his discoveries and inventions. But the change was one of scope rather than of character, and was due to the extension of his environment by the addition to it of his own accumulating knowledge and equipment. Thus, the ore of a metal was at first merely one kind of rock or stone amongst many others, but with increasing discoveries of its potentialities, man's environment was enlarged no less than it would have been if the ore had fallen from the skies, with instructions for use. Similarly, when he discovered that he could make a new kind of weapon or tool by thrusting a blade of stone into a bend or a cleft or a hole in a stick, he opened up a new field of invention, which had previously been outside his environment. Certain discoveries and inventions contained great possibilities, others had their chief value in their immediate utility, and were destined to advance but little. The pestle and mortar are much as they have always been, except in diversity of material, but the pick or the hoe led to the modern plough, and the canoe now figures as a battle-ship. In all the developments, each step has depended upon its predecessors, except in cases in which an appliance or method has reached its highest level only to be superseded by a rival which had evolved along different lines, and which contained greater potentialities. Thus, the spear-thrower gave place to the bow, and this to the gun, the push-quern to the rotary quern, stone-working to metal-working, though where the newer knowledge never penetrated, or met with opposition, the older ways survived.

Method of Variation.—If we take a closer view of the manner in which inventions develop, we find that two chief factors can be distinguished. In the one case, there is the method of variation, in which the individual changes are small in amount and unimportant in their effects, or, if not so small, they are such as could have been produced by the summation of a number of such changes. It is obvious that form and size may easily change as the result of the selection of variations, whether the selection is made with a clear consciousness of possibilities or not. By variation the bronze dagger was lengthened to become a sword, the flanged celt became a palstave, and such artefacts as wooden clubs, stone celts and arrow-heads, pots and a multitude of others developed into a variety of forms without the intervention of what is often called the inventive faculty, though not necessarily without imitation coming into play.

Mutations.—In addition to these variational changes, there are others which can only occur each as a single step of a decisive character. There can be no true intermediate stages, no summation of series, for example, between the worked stone held in the hand, and one fixed in a wooden haft; between the spear with a fixed point, and a harpoon with a detaching point; between a plain bow and a crossbow; between a simple wooden drill and a bow-drill. In all these cases the second appliance arose by an abrupt change, of an inventive character, and we may borrow a biological term and speak of such steps as mutations.

Two kinds of mutations may be distinguished. On the one hand there are improvements made as a result of discoveries arising during the manufacture or utilization of the artefact itself. These we may call free-mutations, and they are strictly comparable with the applied discoveries of the potentialities of natural objects. If we assume that the harpoon arose from a spear which had a bone point or blade tied to the shaft, we may regard the occasional breaking away of the point as the determining accident in the evolution of the new appliance. The tying cord might easily retain its connection with the shaft and become entangled with the point, in such a way that the essential feature of the harpoon presented itself ready-made. The observation that there were certain advantages in this looser mode of attachment might lead to its permanent adoption for spearing fish or aquatic mammals, and the free-mutation established itself. It is not possible to do more than speculate as to the mode of origin of most ancient inventions. In this case, as no doubt in many others, accident may well have played the predominant part.

It is in the second kind of mutations, which may be called cross-mutations, that the inventive faculty has its main opportunity. Here not only is the end pre-conceived, but a possible means is foreseen. Most modern inventions (the single steps, not complexes such as aeroplanes and loud-speakers) are cross-mutations, and they involve the adaptational transfer of a device or feature from one appliance to another, or the application of a device or feature that has become well-known through its utilization in other artefacts. The more highly developed the state of material culture, the more numerous are the opportunities for cross-mutation, though progress is still made step by step. Early man, and even early civilized man, had relatively few such opportunities, but occasionally he hit upon a new method or device that contained extensive possibilities of transfer and adaptation. The

idea of hafting, and the several methods of hafting (by means of lashings, tangs, sockets, etc.) were in origin based on free-mutation and variation; but they could be transferred as cross-mutations. Similarly, devices for utilizing and controlling rotary motion were capable of transfer. We must suppose that such transfer only took place to an artefact which had reached a stage of development at which the application of the mutation was a more or less obvious step to take; nevertheless it is clear that in cross-mutation there was a greater foresight and awareness than in the case of free-mutation, which only involved an appreciation of the immediate possibilities of a chance discovery. A free-mutation is a new discovery directly applied to the construction or improvement of an artefact, whilst a cross-mutation is the result of the extension of the utility of a known device. Any true inventive step is a mutation, and the term may be restricted in its use to the evolution of artefacts.

This "opportunist" view of the manner in which man's methods and artefacts have been evolved, emphasizes the extreme gradualness of the process. The simplest tool and method that are based on the most superficial phenomena, may have been arrived at over and over again. Such knowledge was probably part of the equipment of *Homo sapiens* at the time of his first dispersal. It is evident that the greater the number of determining variations and mutations involved, the less probable is it that the same result will have been reached independently in different parts of the world. The fact that in modern times two investigators occasionally make the same discovery or invent a similar device, has no bearing upon the question, since they work in reality in collaboration, starting from the same point, using similar apparatus, and drawing upon the records of the same predecessors. A consideration of modern inventive progress, in spite of its directional aims, strongly supports the opportunist view of the development of material culture.

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MATERIALISM in philosophy, the theory which regards all the facts of the universe as explainable in terms of matter and motion, and in particular explains all psychical processes by physical and chemical changes in the nervous system (from Lat. *materia*, matter). It is thus opposed both to natural realism and to idealism. For the natural realist stands upon the common-sense position that minds and material objects have equally effective existence; while the idealist explains matter by mind and denies that mind can be explained by matter. The various forms into which materialism may be classified correspond to the various causes which induce men to take up materialistic views. *Naïve materialism* is due to a cause which still, perhaps, has no small power, the natural difficulty which persons who have had no philosophic training experience in observing and appreciating the importance of the immaterial facts of consciousness. The pre-Socratics may be classed as naïve materialists in this sense; though, as at that early period the contrast between matter and spirit had not been fully realized and matter was credited with properties that belong to life, it is usual to apply the term hylozoism (*q.v.*) to the earliest stage of Greek metaphysical theory. *Cosmological materialism* is that form of the doctrine in which the dominant motive is the formation of a comprehensive world-scheme: the Stoics and Epicureans were cosmological materialists. In *anti-religious materialism* the motive is hostility to established dogmas which are connected, in the Christian system especially, with certain forms of spiritual doctrine. Such a motive weighed much with Hobbes and with the French materialists of the 18th century, such as La Mettrie and d'Holbach. The cause of *medical materialism* is the natural bias of physicians towards explaining the health and disease of mind by the health and disease of body. It has received its greatest support from the study of insanity, which is now fully recognized as conditioned by disease of the brain. To this school belong Drs. Maudsley and Mercier. The highest form of the doctrine is *scientific materialism*, meaning the doctrine commonly adopted by the physicist, zoologist and biologist.

It may perhaps be fairly said that materialism is at present a necessary methodological postulate of natural-scientific inquiry. The business of the scientist is to explain everything by the physical causes which are comparatively well understood and to exclude the interference of spiritual causes. It was the great work of Descartes to exclude rigorously from science all explanations which were not scientifically verifiable; and the prevalence of materialism at certain epochs, as in the enlightenment of the 18th century and in the German philosophy of the middle 19th, were occasioned by special need to vindicate the scientific position, in the former case against the Church, in the latter case against the pseudo-science of the Hegelian dialectic. The chief definite periods of materialism are the pre-Socratic and the post-Aristotelian in Greece, the 18th century in France, and in Germany the 19th century from about 1850 to 1880. In England materialism has been endemic, so to speak, from Hobbes to the present time, and English materialism is more important perhaps than that of any other country. But, from the national distrust of system, it has not been elaborated into a consistent metaphysic, but is rather traceable as a tendency harmonizing with the spirit of natural science. Hobbes, Locke, Hume, Mill and Herbert Spencer are not systematic materialists, but show tendencies towards materialism.

Largely through the influence of Bergson, Alexander and Lloyd Morgan contemporary science is tending away from materialism and mechanism towards the recognition of other than mechanical factors in the phenomena, even the physical phenomena, of Nature.

See EMERGENCE, IDEALISM; and F. A. Lange's *History of Materialism* (Eng. Tr. 1926).

MATERIALS, STRENGTH OF, is a branch of applied mechanics which deals with the effects produced by forces in the materials of architectural and engineering construction. Its aims (in so far as these are practical) are to discover rules whereby the strength of a given part may be assessed, and on these to base general principles of design, whereby each member of a structure or machine may be given the material and proportions best suited to its function.

Thus, to take a fairly simple example, the choice of suitable material and proportions for a locomotive coupling rod is a problem which falls within the province of our subject The rod is required to transmit from one wheel to the next a force which will depend upon the speed and on the tractive effort of the locomotive, and which will fluctuate during each revolution of the wheels. In addition, it will be subjected to bending actions, due to its own up-and-down motion, which will depend not only upon the speed of the locomotive but also upon the mass of the rod itself. When the material and proportions have been (provisionally) determined, the magnitudes of these different forces can be estimated: the question then presents itself, whether the strength of the rod will be adequate to its task.

At the outset it is evident that two factors are involved. Whatever be the material, a member will break or bend if its cross-section is too small: whatever be its size, certain properties (such as hardness or rigidity) are required of the material. So, following our subject, two investigations must be pursued. First, we must be able to predict the state of stress (that is, of internal action) which results when specified forces are applied to a body of specified form; secondly, we must be able to decide whether these internal actions can be brought into existence without detriment to a specified material. The first line of investigation is the province of the theory of elasticity; the second, that of metallurgy and the testing of materials: our problem is to combine, for the guidance of the architect or engineer, the knowledge which these different sciences afford.

THEORY OF ELASTICITY

2. For a full account of the methods and results of mathematical enquiry the special article ELASTICITY should be consulted. Much of the theory is concerned with problems of physical rather

than engineering interest, and methods of more restricted range can be employed to obtain those few and relatively simple solutions which form the basis of practical design. The essentials of the theory are: (1) a quantitative analysis of *stress*, or internal action; (2) a quantitative analysis of *strain*, or distortion; (3) postulates (based on experiment) regarding the relation of stress to strain. These, in conjunction with the accepted principles of mechanics, it employs to derive equations which govern the *displacement* at every part of a loaded body. The solution of those equations is a purely mathematical problem, which may present considerable difficulties.

Continuity.—3. The whole theory, as at present developed, rests on a fundamental assumption regarding the nature of materials. These are treated as "continuous," in the sense that they can (in imagination) be subdivided to any extent without losing any property which they exhibit in bulk. In other words, the theory contemplates a material having the nature of a structureless jelly, which would have exactly the same appearance when viewed through a microscope of any imaginable magnification.

The assumption must be recognized and its implications weighed, for it does not accord with our knowledge of real materials. These in all cases exhibit a definite structure, even when examined under low magnifications: brass, for example, is revealed as a conglomerate of small crystals of copper and of zinc. Small pieces cut from different parts would therefore *not* exhibit similar properties; and if we were to subdivide them further, down to molecular or atomic dimensions, we should ultimately reach a stage at which all resemblance to a continuous substance had disappeared.

We shall have to consider later how far it is permissible to apply to real materials results which are based on the assumption of continuity. For the moment we are concerned to develop, in accordance with this assumption, precise notions of stress and strain.

ANALYSIS OF STRESS

The Notion of Stress.—4. Let us imagine, in the first place, that a heavy cube (A) of the structureless material rests with its bottom face horizontal and in contact with a similar cube (B). To maintain equilibrium, an action must be exerted at the surface of contact, whereby B pushes upwards against the weight of A, whilst A pushes down on B with equal force. Mutual action of this kind is termed a *stress:* when, as in this example, its direction is at right angles to the surface at which it acts, it is termed *"normal stress."*

Action of the same kind (although different in amount) must evidently be exerted at any horizontal surface which divides either cube into two parts: the material below the surface must push upwards on that above, and the material above the surface must push downwards on that below. So the idea of stress can be extended from mutual actions between two bodies to mutual actions between different parts of the same body; the reality of the surface across which a stress is transmitted is a matter of indifference.

Again, we may conceive the total action across a surface to be made up of contributions from every part of that surface. In this way we arrive at the notion of *superficial intensity of stress.* If a portion of area S makes a contribution P to the total action, then the ratio P/S measures the average intensity of stress on that area. If S (and therefore P) is indefinitely small, so that the area is effectively concentrated at a point, the average intensity of stress may be identified with the actual local intensity at that point.

We employ the symbol p to denote this local intensity of stress. If equal contributions to the total action are made by equal areas, p will have a constant value over the surface considered; in such cases we say that the intensity of stress is uniform, or that the stress is "uniformly distributed." More generally, p will vary from point to point.

Normal and Tangential Stress.—The action at a given surface will not necessarily be directed at right angles to that surface. Let us imagine that the cube A, in the case already considered, is subjected to a horizontal force F which tends to slide it off B, and that sliding is resisted by friction at the surface of contact. Evidently there is a mutual action between A and B, at this surface, of a kind to which we have given the term stress; and further, action of the same sense and total amount must be exerted across any imaginary horizontal surface, lying below the point of application of F, which divides A into two parts. It would not be legitimate to say that this last action has its origin in friction; but we see the necessity for the concept of stresses, which may or may not be "uniformly distributed," having directions parallel to the surfaces at which they act. Such stresses are termed *tangential*, or *"shearing" stresses.*

Resolution of Stress.—5. In the general case, the action at a surface may have any inclination to that surface. Thus a stress, like a force, may be resolved into components having any three specified directions; and conversely normal and tangential stresses may be superposed, or "compounded."

Simple Longitudinal Stress.—Normal stress of the type already considered will be brought into existence when uniform pressures (that is, distributed normal forces of uniform intensity, acting inwards) are applied to the top and bottom faces of a cube. If the directions of the applied forces are reversed (fig. 1A), the stress across a horizontal surface will have the same direction and magnitude as before, but it will now be opposite in sense. We term it a *tensile stress,* because the applied forces tend to stretch the cube: stress of the former type is termed *compressive.*

Thus we see that normal stress may be of two kinds,—viz., tensile or compressive,—which differ only in respect of sense; compressive stress may be regarded as tensile stress of negative intensity. This convention will be adopted in what follows: we shall use the symbol p to denote tensile stress, and we shall represent compressive stresses by giving a negative sign to p. Tangential stress will frequently be represented by the symbol q.

When a long rod of uniform cross-section is stretched by means of a suspended weight, a practically uniform tensile stress will act on horizontal surfaces, and vertical surfaces will be free from stress. The material is then said to be subjected to "simple longitudinal stress." When a short pillar or block is compressed by opposite forces applied at its ends, we have, to a somewhat less close approximation, a state of simple longitudinal compressive stress.

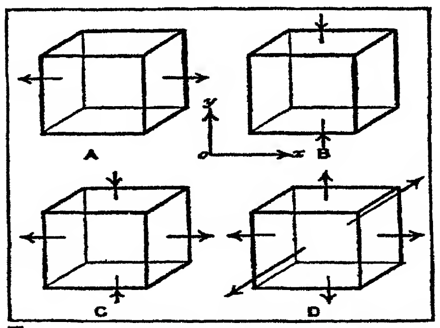


FIG. 1.—SIMPLE AND COMPOUND STRESSES

Compound Stress.—If the rod or block is subjected in addition to forces acting on its sides, a more complex state of stress is presented. We may regard it as a combination of two or more simple longitudinal stresses, and we describe it as a *compound stress.* In fig. 1, the first block (A) is subjected to simple longitudinal stress (tensile) in the direction *ox;* block B is subjected to simple longitudinal compressive stress in the perpendicular direction *oy.* When the two systems of applied force are combined, as in block C, we have a state of compound stress made up of two simple longitudinal components. In block D, three simple longitudinal components go to make up the state of stress.

Principal Stresses.—6. That part of the theory of elasticity which is called analysis of stress deals with the combination of simple stresses and, conversely, with the resolution of compound stresses into their "simple" components. The most important theorem in the subject may be stated as follows:—*At any point in a material, however complicated may be the state of stress at that point, three planes can be found, each perpendicular to the other two, which have the property that the stresses transmitted across them are purely normal.* These planes are termed *principal planes of stress* for the point considered, and the corresponding stresses are termed *principal stresses.*

We may imagine that a very small rectangular block of material, containing the point in question, has its faces parallel to the

three principal planes. The theorem states that only normal stresses will act upon those faces, as shown in case D of fig. 1, which accordingly represents the most general state of compound stress that can occur. The three normal stresses p_1, p_2, p_3 will in general all be different, and one or more may assume negative values (representing compressive stresses, as explained on p. 51).

Stress Equations of Motion or Equilibrium.—7. The directions of the principal stresses will in general vary from point to point, and cannot be determined until we have calculated the state of stress. For this purpose we form, in the first place, the equations of motion or of equilibrium for a small rectangular block of the material having edges parallel to three fixed axes Ox, Oy, Oz: hence, imagining the dimensions of the block to be made indefinitely small, we derive three equations of which the following is typical:

$$\frac{\partial X_x}{\partial x}+\frac{\partial X_y}{\partial y}+\frac{\partial X_z}{\partial z}+\rho X=\rho f_x. \qquad (1)$$

In this equation, x, y and z are the components of a point referred to the fixed axes; X_x is the normal component of the stress on a plane through (x,y,z) which is perpendicular to Ox; and X_y, X_z are the tangential components, parallel to Ox, of the stresses on planes through (x,y,z) which are perpendicular to Oy and Oz respectively. X is the "body force" per unit mass (due, *e.g.*, to gravitation or electrical attractions), ρ the density of the material, and f_x the acceleration in the direction Ox, at the point (x, y, z).

Two-Dimensional Stress-Systems.—8. The derivation of these equations, and a proof of the theorem stated in § 6, will be found in the article ELASTICITY. We shall here confine attention to the special case in which there is no stress on planes perpendicular to Oz.

Fig. 2 shows a rectangular block of dimensions δx, δy, 1, in the directions of Ox, Oy, Oz respectively. The point A has co-ordinates x, y, and the stress on the face AD has a normal component which we denote (as above) by X_x; similarly, the stress on the face AB has a normal component which we denote by Y_y. The tangential stress on AB has a component in the direction of Ox which we denote (as above) by X_y; and similarly, the tangential stress on

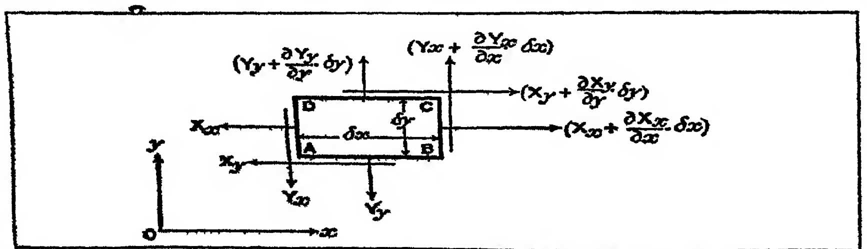


FIG. 2.—DERIVATION OF THE STRESS EQUATIONS OF MOTION: TWO-DIMENSIONAL CASE

AD has a component in the direction of Oy which we represent by Y_x.

On the face BC, as on AD, there will be component stresses X_x, Y_x; but their values will in general be different, because the state of stress will vary from point to point. We may represent them, as in the diagram, by $\left(X_x+\frac{\partial X_x}{\partial x}\cdot\delta x\right)$ and $\left(Y_x+\frac{\partial Y_x}{\partial x}\cdot\delta x\right)$ respectively, and the stresses on DC may be represented similarly.

Remembering that the total action on any face is given by the stress on that face multiplied by its area, we see that the resultant force tending to accelerate the block in the direction Ox is

$$\left(\frac{\partial X_x}{\partial x}\ \delta x\right)\ \delta y+\left(\frac{\partial X_y}{\partial y}\ \delta y\right)\ \delta x+\rho X\ \delta x\ \delta y,$$

where X is the body-force. This resultant may be equated to the product of mass and acceleration—that is, to $(\rho\ \delta x\ \delta y)\ f_x$. Then, if we cancel out the common factor $(\delta x\ \ \delta y)$, we obtain the equation

$$\frac{\partial X_x}{\partial x}+\frac{\partial X_y}{\partial y}+CX=\rho\ f_x,$$

which (since we have assumed that X_z is zero) is the same as (1).

9. A second equation may be obtained by considering motion in the direction Oy, and a third by considering the tendency of the block to turn about an axis parallel to Oz. The resultant moment on the block is given by

$$(Y_x\ \delta y)\ \delta x-(X_y\ \delta x)\ \delta y,$$

plus terms which become relatively negligible when δx and δy are indefinitely reduced. So we have, ultimately, the condition

$$Y_x=X_y, \qquad (2)$$

which is typical of three that can be obtained in the general case. Thus in general six (not nine) components are required to specify the state of stress at a point, namely,

$$X_x,\ Y_y,\ Z_z,\ Y_z,\ Z_x,\ X_y, \qquad (3)$$

and these six components are related by three equations of the type (1).

10. To illustrate the theorem of § 6, we shall again assume that planes perpendicular to Oz are free from stress. We shall consider the triangular block shown in fig. 3, and we shall imagine that the sides of this block are indefinitely small; then the effects of body-force and of acceleration may be neglected in comparison with those of stress. In accordance with (2), we denote by X_y the tangential stress on both of the faces AC, CB.

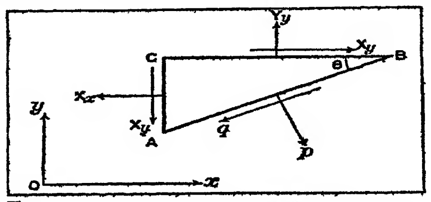


FIG. 3.—TRANSFORMATION OF STRESS COMPONENTS: TWO-DIMENSIONAL CASE

Let p and q be the (unknown) normal and tangential components of stress on the inclined face AB. Then for equilibrium in the direction of p we have the condition

$$p\ AB=(X_x\ AC)\sin\theta+(Y_y\ CB)\cos\theta$$
$$-X_y(AC\ \cos\theta+CB\ \sin\theta),$$

and for equilibrium in the direction of q we have similarly

$$q\times AB=(Y_y\times CB)\sin\theta-(X_x\times AC)\cos\theta$$
$$+X_y(CB\ \cos\theta-AC\ \sin\theta).$$

But $AC=AB\sin\theta$ and $CB=AC\cos\theta$. Hence, dividing out both equations by AB, we obtain the expressions

$$\left.\begin{aligned} p&=X_x\sin^2\theta+Y_y\cos^2\theta-X_y\sin 2\theta,\\ q&=\frac{Y_y-X_x}{2}\sin 2\theta+X_y\cos 2\theta,\end{aligned}\right\} \qquad (4)$$

whence p and q can be found when X_x, Y_y, X_y are known.

The stress on AB will be purely normal if q is zero, and the second of (4) shows that this will happen if

$$\tan 2\theta=\frac{2X_y}{X_x-Y_y}, \qquad (5)$$

—an equation which gives two values of θ, differing by a right angle. Thus, in our simplified case, the theorem is proved.

The first of (4) may be written in the form

$$p=\frac{X_x+Y_y}{2}+\frac{Y_y-X_x}{2}\cos 2\theta-X_y\sin 2\theta,$$

and hence p will have a stationary value if

$$0=\frac{\partial p}{\partial\theta}=(X_x-Y_y)\sin 2\theta-2X_y\cos 2\theta.$$

Comparing this condition with (5), we see that the normal stress will have stationary (*i.e.*, maximum or minimum) values on those planes for which the tangential stress is zero. This theorem holds in the general case.

Mohr's Circle Diagram for Compound Stress.—11. If, in fig. 3, the rectangular faces are principal planes of stress, X_y will be zero. Writing p_1 and p_2, in (4), for Y_y and X_x respectively, we have for this case:

$$\left.\begin{aligned} p &= \tfrac{1}{2}(p_1+p_2)+\tfrac{1}{2}(p_1-p_2)\cos 2\theta, \\ q &= \tfrac{1}{2}(p_1-p_2)\sin 2\theta. \end{aligned}\right\} \quad (6)$$

It is clear that p and q will be given, in terms of p_1, p_2, by a circular diagram constructed as shown in fig. 4. If CA is drawn, at an angle 2θ to OCN, to meet the circle at A, the co-ordinates ON, AN of A will represent p and q respectively.

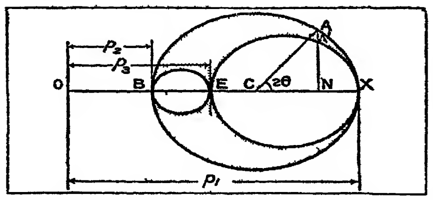


FIG. 4.—MOHR'S CIRCLE DIAGRAM FOR COMPOUND STRESS

Again, it is clear that the stress on AB (fig. 3) will not be affected by the addition of a third principal stress p_3, acting on the triangular faces of the prism; so, in the general case, the circle BAX still gives the stresses on planes which are parallel to the direction of p_3. In the same way, if OE (fig. 4) represents p_3, points on a circle having EB as diameter will relate the normal and tangential components of stress for all planes parallel to p_1, and points on a circle having EX as diameter will relate these components for all planes parallel to p_2.

On planes which are inclined to all three of the principal planes, the stresses, in the general case, will depend upon all three of p_1, p_2, p_3. But it may be proved that points taken, in fig. 4, to relate the normal and tangential components of stress on such planes will in all cases lie within the shaded area of the diagram. Thus, if the normal stress on a plane is specified by ON, the intensity of the tangential stress lies between limits given by AN and $A'N$.

Case of Two Equal and Opposite Principal Stresses.—12. If, in equations (6), we make p_2 equal and opposite to p_1, the stress on planes which are equally inclined to the principal planes of stress ($2\theta=90°$) will be given by

$$p=0, \qquad q=p_1. \quad (7)$$

Hence we see that a state of stress represented by equal and opposite principal stresses of intensity p and $-p$ is equivalent to a state of simple shearing stress, of intensity p, on planes inclined at 45° to the principal planes of stress.

ANALYSIS OF STRAIN

Displacements.—13. In the analysis of strain, or distortion, the assumption of continuity is again fundamental. Disregarding all questions of molecular structure, we imagine our ideal material to occupy every point within a certain continuous surface (or within a volume contained by continuous surfaces, when the body considered is hollow)—the "boundary" of the solid body considered. When the material is distorted by the application of force, this boundary surface will assume a different form; but so long as the material is unbroken, it will remain a continuous surface.

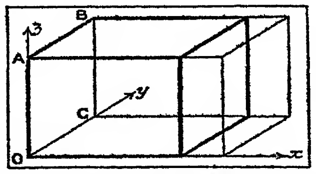


FIG. 5.—DIAGRAM ILLUSTRATING SIMPLE EXTENSION

In the unstrained body there will be, at any point defined by co-ordinates x, y, z, a certain "particle" of material. When the body is distorted, this particular particle will in general occupy a different position, which we may define by co-ordinates $x+u$, $y+v$, $z+w$; u, v, w are termed the component *displacements* of the particle in question. It is clear that, if we know the component displacements of any two particles P and Q, we can calculate the increase, due to strain, in the distance PQ; and further that, if we know the component displacements of a third point R, we can calculate the change, due to strain, in the angle PQR.

Simple Extension.—14. Let us imagine, for example, that a cube of the material is distorted in the manner which is indicated by fig. 5, so that four of its edges are lengthened by the same amount, whilst the other eight edges retain their original lengths and all the faces remain rectangular. If we choose axes Ox, Oy, Oz coinciding with three edges of the cube, as shown, it is clear that this state of strain will occur when every particle undergoes a displacement confined to the direction of Ox and of magnitude proportional to its original distance from the face $OABC$; then we shall have

$$u=ex, \quad v=0, \quad w=0,$$

where e is constant, and the fractional extension of any line PQ having the direction Ox will be given by

$$\frac{\text{(Strained length)}-\text{(Original length)}}{\text{(Original length)}} = \frac{u_Q-u_P}{x_Q-x_P}, \\ = \frac{e(x_Q-x_P)}{x_Q-x_P}, \\ = e.$$

We say that the material undergoes a simple extension, of amount e, in the direction Ox: any line in the material, initially parallel to this direction, is extended by the same fractional amount

Simple Shearing Strain.—15. Another simple type of distortion can be imagined in which the shape of two faces is changed. Its nature is illustrated in fig. 6, and it will evidently occur when every particle undergoes a displacement confined to the direction Ox and of magnitude proportional to its distance from the face $OCEF$, for then we shall have

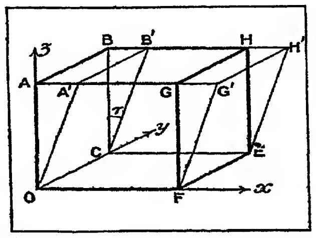


FIG. 6.—DIAGRAM ILLUSTRATING SIMPLE STRESS

$$u=\gamma z, \quad v=0, \quad w=0,$$

and all lines originally parallel to OZ will rotate through the same angle (the angle BCB' of the figure). If BB' is small, this angle will be represented sufficiently closely (in circular measure) by the ratio

$$\frac{BB'}{BC}=\frac{\gamma\cdot BC}{BC}=\gamma.$$

We say that the material undergoes "simple shearing strain" (or, more briefly, "simple shear") in the (z, x) plane; the magnitude of the strain is γ, the reduction in the angle between lines which were originally parallel to Oz and Ox.

Composition of Simple Strains: Principle of Superposition.—16. Suppose that the top face $ABHG$, after moving to the position $A'B'H'G'$, undergoes a further displacement in its own plane, this time in the direction Oy. We may imagine that the edges OA, CB, EH, FG, and any line of particles which was originally parallel to them, again remain straight and parallel; they now rotate through another angle γ; which is the reduction (in circular measure) in the (originally right) angle AOC. We say that a second simple shearing strain has been superposed on the first.

Evidently, only the top and bottom faces of the cube will remain rectangular after this second strain is imposed, and these can have their angles changed by the imposition of a third simple shear. In its final state, the body will be bounded by six parallelograms, and opposite faces will be similar; that is to say, the cube has distorted into a parallelopiped. Since the lengths of its edges are unaltered by the distortion, three quantities (namely, three angles of shear γ_1, γ_2, γ_3) are required to specify its final shape.

Lastly, we may imagine that the material undergoes three successive simple extensions in the three perpendicular directions Ox, Oy, Oz. Denoting these extensions by e_1, e_2, e_3, defined as above, we see that the three sets of parallel edges of the parallelopiped will be increased in the ratios $(1+e_1)$, $(1+e_2)$ and $(1+e_3)$. These expressions are not strictly correct, but they are sufficiently accurate if e_1, e_2, e_3 are small; for on this understanding the final shape would have been the same if the extensions had been imposed first and the shearing strains last. This is the *principle of superposition* for small strains.

Homogeneous Strain.—17. In these examples of simple

strain;[1] the same description and diagrams would evidently apply to any cubical portion of the material, however small. In such circumstances the strain is said to be *"homogeneous,"* or uniform.

It is a fundamental principle in the analysis of strain that *in the immediate neighbourhood of any point, whatever may be the nature of the distortion, the strain is sensibly homogeneous;* in other words, whilst we can imagine types of distortion in which the faces and edges of a cube become curved, and in which opposite faces are unequally strained, it is permissible, when the dimensions of the cube are indefinitely diminished, to neglect these effects and to assume that the strained cube is a parallelopiped. This implies, according to the preceding investigation, that the most general type of strain at any point in a material may be described by specifying values of three extensions and three angles of shear These six quantities are termed the "components of strain."

Strains Expressed in Terms of Displacement.—18. On the assumption that the displacements u, v, w are everywhere small, it may be shown (*see* article ELASTICITY) that the extension in the direction Ox will be given by

$$e_{xx}=\frac{\partial u}{\partial x},$$

and the "shear" in the (z, x) plane by (8)

$$e_{zx}=\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}.$$

Similar expressions hold for the other four components of strain. Thus the six components of strain are not really independent: they can all be expressed in terms of three component displacements $u, v, w,$ when these are given as functions of $x, y, z,$ the co-ordinates of a particle in the unstrained material.

Transformation of the Components of Strain.—19. Given the values of $u, v, w,$ we can evidently calculate the component displacements, $u', v', w',$ in any other three perpendicular directions $Ox', Oy', Oz',$ and hence we can deduce expressions, *e.g.*, for the extension in the direction Ox' and for the shear in the (z', x') plane. This is the problem of "transformation of strain-components": the general formulae will be found in the article ELASTICITY, and it will suffice here to give a relatively simple example.

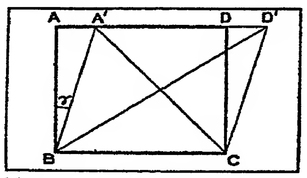


FIG. 7.—DIAGRAM ILLUSTRATING TRANSFORMATION OF STRAIN COMPONENTS

Consider a square block $ABCD$ which undergoes a simple shearing strain of magnitude γ, as shown in fig. 7. The diagonals AC, BD will evidently remain perpendicular to one another, and the angle $A'BD'$ will be $\left(45°-\frac{\gamma}{2}\right)$; to the first order of small quantities, the sides AB, BC, CD, DA will retain their original length l. Hence, the strained length BD' will be given by

$$2l\cos\left(45°-\frac{\gamma}{2}\right)=\sqrt{2}\cdot l\left(1+\frac{\gamma}{2}\right);\text{ very nearly, since }\gamma\text{ is small.}$$

That is to say, the fractional extension of BD is

$$\sin\frac{\gamma}{2}=\frac{1}{2}\gamma. \tag{9}$$

The fractional extension of AC may be shown in the same way to be $-\frac{1}{2}\gamma$. So we see that a state of strain represented by equal and opposite extensions of amounts e and $-e$ in two directions at right angles implies a simple shearing strain of amount $2e$ in an element whose sides are equally inclined to these directions.

Principal Strains.—20. The fundamental theorem in the analysis of strain may now be stated:—*Through any point in the material, however complicated may be the state of strain at that point, three lines can be found, each perpendicular to the other two, which were also perpendicular to one another initially, when the material was unstrained.* In other words, a very small rectangular block of material, whose edges were originally parallel to these lines, will remain rectangular after strain. The most general type of distortion may be specified by fixing these three directions, and the extension which corresponds to each[1]: the extensions are called *"principal extensions,"* and the directions *"principal axes of strain"*

In the two-dimensional example just considered, the diagonals AC, BD are the principal axes of strain.

THE RELATION OF STRESS TO STRAIN

21. We have seen (§ 9) that *six* independent quantities (the "stress-components") are required, in general, to specify a state of stress; and further (§ 7), that *three* relations between them (the "stress equations" of motion or equilibrium) can be obtained by an application of dynamical principles. These relations are not sufficient to determine the stress-distribution produced by specified loads; to take a simple example, we cannot, by statical considerations alone, determine the load on each leg of a table, when all four are in contact with the ground. We need additional relations, and an obvious solution of the difficulty is to relate, by any arbitrary assumption, the six components of stress with the six components of strain. For we have seen (§ 18) that the latter can all be expressed in terms of *three* independent quantities—the components of displacement; so, by this procedure, we shall be left with three equations relating only three unknown quantities—that is, with information sufficient (*i.e.*, in theory) for a solution.

Hooke's Law.—22. The simplest relation that we can assume is direct proportionality—in other words, a "linear" law. The most general state of stress is defined by six independent components of stress, and the most general state of strain is defined by six independent components of strain: we assume that each one of the components of stress may be expressed in terms of the six components of strain by a formula of the type

$$p=a_1e_1+a_2e_2+a_3e_3+a_4e_4+a_5e_5+a_6e_6, \tag{10}$$

where p stands for the stress-component, $e_1, \ldots e_6$ for the components of strain, and $a_1, \ldots a_6$ are constants. On this assumption, the stress equations remain linear when transformed, first into relations between the coefficients of strain, and thence into relations between u, v and $w,$ the three components of displacement. Hence, if we obtain a solution—that is to say, expressions for $u, v, w,$ at any point in a specified body, in terms of the applied forces—these relations will still be satisfied when we multiply $u, v, w,$ together with the applied forces, by any constant factor. So we deduce from our assumption, that the displacements at every point, and hence the strains, will be proportional to the "load."

Robert Hooke, in 1660, discovered by experiment that this is in fact a property of real materials. He published his discovery (1676) under the form of an anagram, *ceiiinosssttuu* and did not until two years later disclose the solution—*"ut tensio sic uis (vis)"*; that is, "the Power of any spring is in the same proportion with the Tension thereof." (*De Potentia restitutiva*, London, 1678.) A more accurate statement of the experimental evidence is that, within certain definite limits of strain (*see* § 38):

(1) when the load is increased, the measured strain increases in the same ratio,

(2) when the load is diminished, the measured strain diminishes in the same ratio.

(3) when the load is reduced to zero, no measurable strain persists.

It will be realized that the assumption represented by (10), whilst it is consistent with these results, is more precise and of wider scope than any experiments that can be made. No method has been devised for measuring either the strain or the stress in the *interior* of an elastic body: all that can be done is to relate particular displacements with the resultant applied load. Thus the six expressions of type (10) are to be regarded as *postulates* of the mathematical theory, and the justification for applying this theory to real materials must be found in an increasing accumulation of observations in which its predictions are verified.

Aeolotropic and Isotropic Materials.—23. Since six coefficients (of type $a_1, a_2, \ldots$ etc.) are involved in each of the six expressions of type (10), our generalized statement of Hooke's

[1]It will be noticed that six quantities are still involved in the description.

law involves altogether 36 coefficients—the "elastic constants" of the material. An argument based on thermodynamical considerations indicates that only 21 of the elastic constants are to be regarded as independent; and on a certain hypothesis concerning the structure of real materials it may be shown that their elastic behaviour will be reproduced in an ideal material for which the number is further reduced to 15[1]. But a much more drastic reduction can be effected if we assume that our ideal material has the same elastic properties in all directions: this property is termed *isotropy*.

Isotropy is not a property of wood, which is well known to have its greatest strength "along the grain"; nor is it found, in experiment, to be a property of crystals: to represent such materials, we must assume this ideal material to be *aeolotropic*—that is, to have elastic constants which vary with direction. Wrought metals, on the other hand, behave as isotropic substances, in the sense that specimens cut from the same material, but in different directions, behave similarly under tests. Thus the assumption of isotropy, which greatly simplifies our calculations, is legitimate for most practical applications of the theory. We shall not discuss aeolotropic materials further in this article.

Stress-strain Relations in Isotropic Material.—24. For isotropic materials we may show that the number of independent constants cannot exceed *two*. For we have seen, in the analysis of stress (§ 6), that a small rectangular block can be found, at any point in the material, whose faces are subjected to purely normal stresses; and in the analysis of strain (§ 20), that a small rectangular block can be found whose faces remain rectangular after strain. The stresses on the faces, in the first case, are termed "principal stresses," and the extensions of the edges, in the second case, are termed "principal extensions, or strains." Now it is clear that, in material which has no directional property, the directions of the principal stresses and of the principal strains must coincide; for there is no reason why a symmetrical system of purely normal stresses should produce asymmetrical distortion, as would be the case if the block ceased to be rectangular. Therefore, in the most general statement of Hooke's law for isotropic materials, we have to relate three principal stresses with three principal strains; and our formulae will thus be three of the type

$$p_1 = ae_1 + be_2 + ce_3, \tag{11}$$

where a, b, c are elastic constants.

But considerations of symmetry demand further, in the absence of directional properties, that the coefficients b and c shall be equal; for it is evident that e_2 and e_3, which both have directions perpendicular to p_1, can be interchanged without altering the magnitude of p_1. So the formula (11) becomes

$$p_1 = ae_1 + b(e_2 + e_3),$$

and this may conveniently be written in the equivalent form

$$p_1 = \lambda\Delta + 2\mu e_1, \tag{12}$$

where Δ denotes the quantity $(e_1+e_2+e_3)$, and λ and μ are two elastic constants of the material which, unless related by some additional hypothesis, will be independent.

Modulus of Compression.—25. Adding the three equations of type (12), we see that

$$p_1 + p_2 + p_3 = (3\lambda + 2\mu)\Delta,$$

so that, if $p_1 = p_2 = p_3 = p$ (say), we have

$$3p = (3\lambda + 2\mu)\Delta \tag{13}$$

Now Δ may be interpreted as the fractional increase in volume which results from the distortion considered. For if the sides of our rectangular block were l_1, l_2, l_3 before strain, they will be $(1+e_1)l_1$, $(1+e_2)l_2$, $(1+e_3)l_3$ after strain, and hence the strained volume will be given by

$$l_1 \cdot l_2 \cdot l_3(1+e_1)(1+e_2)(1+e_3), =$$
$$l_1 \cdot l_2 \cdot l_3 \cdot (1+e_1+e_2+e_3),$$

very nearly, if e_1, e_2 and e_3 are small quantities. Therefore the increase in volume due to strain is

$$l_1 \cdot l_2 \cdot l_3 \cdot \Delta,$$

and the fractional increase is Δ, very nearly.

Let us now suppose that our material is strained by hydrostatic pressure. Then the relation (13) will hold, both p and Δ being negative. If we write k for the ratio

$$\frac{\text{Intensity of Pressure}}{\text{Consequent reduction in volume}},$$

we have

$$k = \frac{-p}{-\Delta} = \frac{3\lambda + 2\mu}{3}, \text{ by (13).} \tag{14}$$

The quantity k is termed the *modulus of compression* or *bulk modulus* of the material.

Modulus of Rigidity.—26. Let us next suppose that e_1 and e_2 are equal in magnitude and opposite in sign, and that e_3 is zero. Then Δ will be zero, and we have as relations of the type (12):

$$\left.\begin{array}{l} p_1 = 2\mu e_1, \\ p_2 = 2\mu e_2, \end{array}\right\} \text{so that } p_1 = -p_2,$$
$$p_3 = 0.$$

The state of stress is that considered in § 12, and the state of strain is that considered in § 19. It will be seen that the stress may be regarded as a simple shearing stress of intensity p_1, and the strain as a simple shear of amount $2e_1$. Therefore

$$\mu = \frac{p_1}{2e_1} = \frac{\text{Intensity of shearing stress}}{\text{Consequent shear}}. \tag{15}$$

The quantity μ is termed the "modulus of rigidity," or "shear modulus" of the material. From the physical standpoint, k and μ are to be regarded as the fundamental elastic constants: k measures the resistance to change of volume unaccompanied by change of form, whilst μ measures the resistance to change of form unaccompanied by change of volume.

Young's Modulus and Poisson's Ratio.—27. The conditions in a simple tensile test are such that, very approximately,

$$p_2 = p_3 = 0,$$

so that e_1, e_2, e_3 will all be proportional to p_1, the longitudinal tension.

Considerations of symmetry require that e_2 and e_3 shall be equal, but we may not assert that they are zero: in tests on actual materials it is found that e_2 and e_3 are finite and opposite in sign to e_1. If then we write

$$e_2 = e_3 = -\sigma e_1,$$

the relations of type (12) become

$$p_1 = \{\lambda(1-2\sigma) + 2\mu\}e_1,$$
$$0 = \lambda(1-2\sigma) - 2\mu\sigma,$$

and we deduce that

$$\left.\begin{array}{l} \sigma = \dfrac{1}{2}\,\dfrac{\lambda}{\lambda+\mu}, \\ p_1 = 2\mu(1+\sigma)e_1. \end{array}\right\} \tag{16}$$

The ratio

$$\frac{p_1}{e_1} = \frac{\text{Longitudinal stress}}{\text{Consequent longitudinal extension}}$$

is termed *Young's Modulus* for the material, and is generally denoted by the symbol E. We see from (16) that

$$E = 2(1+\sigma)\mu = \frac{\mu(3\lambda + 2\mu)}{\lambda + \mu}. \tag{17}$$

The ratio

$$\sigma = \frac{\text{Lateral contraction}}{\text{Longitudinal extension}} = \frac{1}{2}\,\frac{\lambda}{\lambda+\mu}$$

is termed *Poisson's Ratio*.

[1] *cf.* A. E. H. Love, *Mathematical Theory of Elasticity* (1927), § 66. The relations which effect this reduction in the number of the elastic constants are known as "Cauchy's relations."

We observe that the three equations of type (12) are equivalent to three of the type

$$e_1 = \frac{1}{E}[p_1 - \sigma(p_2 + p_3)]. \tag{18}$$

Relations Between the Elastic Constants. Conditions for Stability.—28. However we express the stress-strain relations, only two independent constants (namely λ and μ) are really involved: therefore any three of the foregoing elastic constants can be related. Thus we have expressed E, in (17), in terms of λ and μ; similarly, from (14) and the first of (16) we have

$$k = \mu\left(\frac{2}{3} + \frac{\lambda}{\mu}\right) = \frac{2}{3}\mu\frac{1+\sigma}{1-2\sigma} = \frac{E}{3(1-2\sigma)}, \tag{19}$$

whence
$$\left.\begin{aligned} \sigma &= \frac{1}{2}\,\frac{3k-2\mu}{3k+\mu}, \\ \text{and}\quad E &= \frac{9\mu k}{3k+\mu}. \end{aligned}\right\} \tag{20}$$

Now it is an observed property of real materials (and an evident condition of their persistence) that the elastic constants E, μ, k, shall all be positive. It follows from (17) that σ cannot be negative and numerically greater than 1; for otherwise the ratio E/μ would be negative. And since $(1+\sigma)$ is thus shown to be positive, it follows from (19) that σ cannot be positive and greater than $\frac{1}{2}$; for otherwise the ratio k/μ would be negative. Thus we have as the condition for a stable material,

$$-1 < \sigma < \tfrac{1}{2}. \tag{21}$$

In ordinary materials σ has a value between 0·25 and 0·33.

SOME SIMPLE STRESS-DISTRIBUTIONS

Tension.—29. Turning from the methods to the results of mathematical enquiry, we remark that some of its simplest solutions are those which have proved most useful to the practical engineer. Thus the "tie," or member subjected to tensile load, is one of the commonest of structural units: theory states that the stress in a straight tie of uniform cross-section will be a simple tensile stress of uniform intensity, provided that the line of the resultant pull passes through the centroid, or centre of area, of each cross-section. At the ends this simple stress-distribution will be modified according to the manner in which the load is applied; but theory shows that the modification is unimportant, except in the immediate neighbourhood of the ends. Thus, when we subject a straight rod of material to a tensile test, it does not matter how the load is applied, provided that the line of the pull is accurately central, and that the resulting strain is measured over a limited part of the length, remote from the loaded ends.

Bending.—30. Another structural unit of very common occurrence is the beam or girder, a member whose function is to resist *bending*. B. de St. Venant (1856) first put the theory of bending on a satisfactory basis (J. de Math. [Liouville], Ser. 2, vol. 1). He showed that a state of stress can be maintained in a straight beam of uniform section, such that there is at every point a purely longitudinal stress (either tensile or compressive). The intensity of this stress depends upon the position of the point: in any cross-section of the beam (fig. 8) there will be a line NN such that at points on this line the stress is zero; at any other point P, the intensity of stress will be proportional to y, the distance of P from NN. NN will always pass through the centroid of the cross-section: if this has a plane of symmetry (QQ in the figure) which is also the plane of bending, then NN will be perpendicular to that plane.

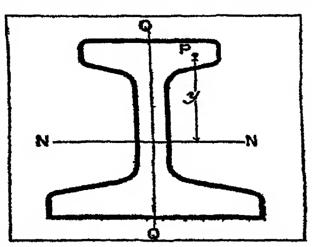


FIG. 8.—STRESSES DUE TO BENDING

Let R be the radius of the (very large) circle into which the beam is bent; let I be the "geometrical moment of inertia" of the cross-section about the line NN; and let E be Young's modulus for the material. Then the longitudinal stress p at P (acting at right angles to the cross-section) will be given by

$$p = \frac{Ey}{R}, \tag{22}$$

and the total bending action M (which is resisted by this distribution of stress) will be given by

$$M = \frac{EI}{R}. \tag{23}$$

Hence we have also

$$p = \frac{My}{I}. \tag{24}$$

These results apply, strictly, to a beam which is bent by forces applied in a particular way (*i.e.*, so as to produce the foregoing distribution of stress on the terminal sections); but theory indicates reasons why the results may, with an accuracy sufficient for practical purposes, be extended to beams bent in any manner, and even to beams of varying cross-section. The results (22)–(24) thus form the basis of a very general theory of bending.

Torsion.—31. Much use is made in mechanical engineering of circular shafts which transmit couples from one end to the other: for example, the propeller shaft of a steamship transmits a couple from the engine or turbine to the propeller, where this couple is opposed by the reaction of the water. Such couples tend to twist the shaft, and in this problem again the state of stress is, fortunately, simple. Let AB (fig. 9) be a uniform circular shaft held at the end A and twisted by a couple applied in the plane B. In consequence of the strain due to twisting (this is very much magnified in the diagram) a radius CD in the plane B remains straight but turns round to CD', and a line AD, originally parallel to the axis of the shaft and at a distance r from it, distorts into a helix AD'—that is, into a curve which makes a constant angle θ with lines parallel to the axis. Cross-sections of the shaft remain plane when the shaft is twisted and hence θ is the angle of shear: so, at a distance r from the axis, we have a shearing stress, of intensity

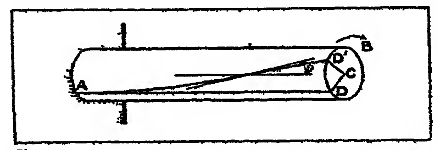


FIG. 9.—STRESSES DUE TO TWISTING

$$q = \mu\theta, \tag{25}$$

acting on each cross-section in a direction perpendicular to the radius.

Now let i denote the angle of twist DCD', and let l be the length of the shaft. Then i and θ (both being assumed very small) are related by the equation

$$l\theta = ri,$$

whence, by (25),

$$q = \mu\frac{i}{l}r = \mu\tau r, \tag{26}$$

where τ is the "angle of twist per unit length." That is to say, the intensity of shear stress at any point in the cross-section is proportional to r, the distance of that point from the axis.

The total twisting couple T (which is resisted by this distribution of shear stress) is given by

$$T = \int 2\pi r^2 q\,dr = 2\pi\mu\tau\int r^3 dr = \mu\tau J, \tag{27}$$

where J is the "geometrical polar moment of inertia" of the cross-section (either solid of hollow) about the axis. So we have, from (26) and (27),

$$q = \frac{Tr}{J}. \tag{28}$$

It should be emphasized that these formulae apply only to shafts of circular cross-section.

Principle of Superposition. Bending Combined with Twist.—32. A consequence follows from the fact that the elastic equations are linear in form. If we can calculate the stresses, strains or displacements which result when any two systems of load act separately on a given body, then we know that these two systems, acting simultaneously, will produce stresses, strains or

displacements which may be found by adding their separate effects. We say that stresses, strains or displacements may be *superposed.*

33. As an example of the use of this principle, we may consider the important problem of a crank (fig. 10). Let a force P be applied to the crank pin A at right angles to the plane of the crank. Then the stresses exerted at any section C of the shaft have to resist, first, a twisting moment of magnitude

$$T = P{\cdot}AB,$$

and secondly, a bending moment of magnitude

$$M = P{\cdot}BC.$$

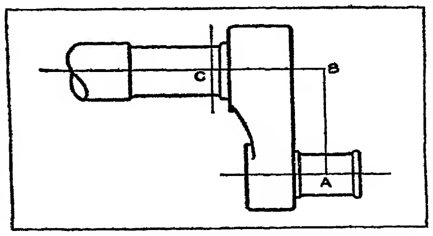


FIG. 10.—STRESSES IN A CRANK

There will also be shear stresses required to resist the direct force P; but these may be neglected as unimportant for practical purposes. The principle of superposition asserts that the stress at C is made up of a normal stress p, due to bending, which may be calculated by means of (24), and of a shearing stress q, due to torsion, which may be calculated by means of (28). We have, in fact, at the surface,

$$p = \frac{4M}{\pi a^3}, \qquad q = \frac{2T}{\pi a^3}, \tag{29}$$

where a is the radius of the shaft (assumed solid).

Stresses Due to Internal Pressure, in Thin Circular Tubes or Spherical Shells.—34. When a long circular tube of uniform thickness is subjected to uniform internal pressure, considerations of symmetry show that the stresses exerted across any plane which contains the axis will be purely normal; moreover, if the thickness is small, this normal stress must be practically uniform. Let t be the thickness of the tube, r the inner radius, P the internal pressure, and p the stress; then, considering any length l of the tube, we see that a total force due to pressure, of amount

$$l \times 2r \times P,$$

is balanced by a total resistance due to stress, of amount

$$2(l \times t \times p).$$

Hence we deduce that

$$p = P\frac{r}{t}. \tag{30}$$

35. A similar argument may be employed to find the stress imposed by uniform pressure on a thin spherical shell. Using the same notation, we see that a total force due to pressure, of amount

$$\pi r^2 \times P,$$

is balanced by a total resistance due to stress, of amount which is given approximately by

$$2\pi r \times t \times p.$$

Hence, in the spherical shell, the stress is given by

$$p = \tfrac{1}{2}P\frac{r}{t}. \tag{31}$$

36. If the ends of a circular tube are closed, the pressure on the ends will impose a stress, on planes which are perpendicular to the axis, of intensity given by (31). The stress on axial planes is given by (30), and the radial stress (which varies from $-P$ at the inner face to zero at the outer face) is relatively negligible. So the tube will undergo circumferential and axial extensions which, by the formulae (18) of § 27, are

$$\left.\begin{aligned} e_1 &= \frac{1}{E}\left[P\frac{r}{t} - \sigma\left(\tfrac{1}{2}P\frac{r}{t}\right)\right] = \frac{2-\sigma}{2E}P\frac{r}{t}, \\ e_2 &= \frac{1}{E}\left[\tfrac{1}{2}P\frac{r}{t} - \sigma\left(P\frac{r}{t}\right)\right] = \frac{1-2\sigma}{2E}P\frac{r}{t}. \end{aligned}\right\} \tag{32}$$

We see from the second of (32) that the longitudinal extension is related with the dimensions of the tube by an elastic constant $E/(1-2\sigma)$ which we have shown (§ 28) to be equal to $3k$. We have in fact

$$e_2 = \frac{1}{6k}P \cdot \frac{r}{t}. \tag{33}$$

This result has been utilized in the experimental determination of k (*see* § 48).

APPLICATION OF THE THEORY TO REAL MATERIALS

Scope of the Theory.—37. The theory of elasticity, and hence the solutions which it provides, are based upon three main assumptions, namely:

(a) that the material, and therefore the displacement, are "continuous";
(b) that "Hooke's law" is satisfied;
(c) that the strains and displacements are everywhere small.

Only when these assumptions are justified will the foregoing solutions be strictly valid.

Now real materials, as we have seen, are not continuous at all: timber, for example, has a "grain" which can be seen with the naked eye, and metals, examined under the microscope, are found to be conglomerates of small crystals, in general arranged at random. But their structure is invariably fine in relation to the sizes of members used in engineering construction, or of the pieces in which they are tested for strength and rigidity; hence its exact nature is a question of minor importance to the practical designer, who (with certain exceptions which will be stated later) is concerned to know the general nature, rather than the finer details, of the stress-distributions which occur. We may legitimately employ "statistical" rather than exact methods, carrying over to real problems the concepts and notation which our theory has developed in relation to ideal continuous materials.

This is the standpoint adopted in the second branch of our subject, the science of testing of materials. When we stretch a rod of steel in a testing machine, and measure the resulting extension, we interpret our results as giving relations between stress and

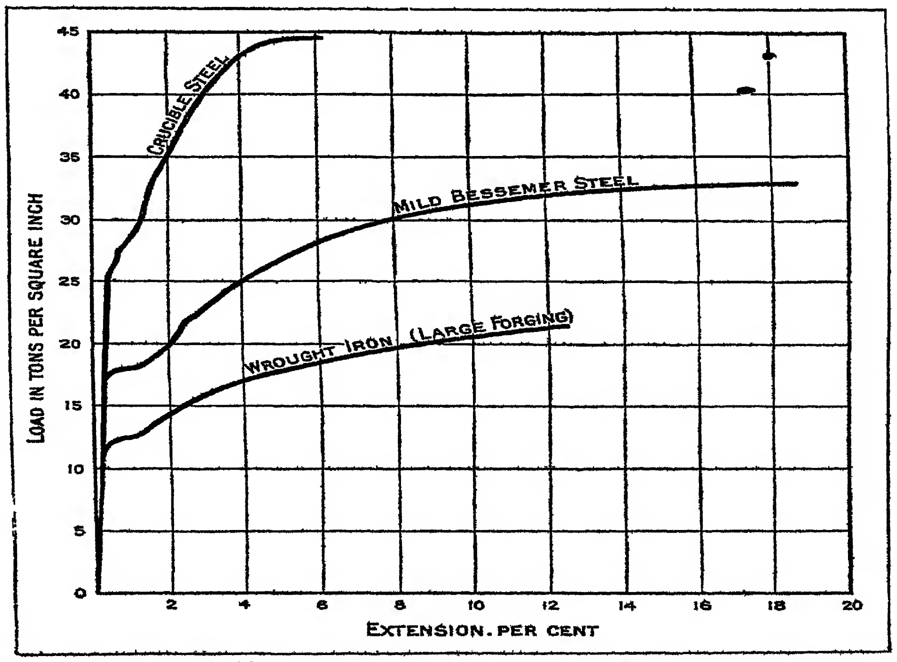


FIG. 11.—STRESS-STRAIN DIAGRAMS

strain. We calculate the stress, in accordance with our theoretical definition (§ 4), as the quotient of the total load divided by the cross-sectional area of the rod; we measure the extension of some definite length of the rod, and calculate the strain, again in accordance with theory (§ 14), as the corresponding fractional extension; and we assume, on grounds which are afforded by the theory (§ 29), that the stress and strain are uniform. That is to say, we treat the material as continuous, disregarding all effects which depend upon its detailed structure. Further, in dealing with steel

or other wrought metal, we treat the material as *isotropic,* although we know that the crystals composing it have properties which depend on direction. This is legitimate from the practical standpoint, because the random orientation of the crystals renders the material *"statistically isotropic"* (*cf.* R. V. Southwell and H. J. Gough, *Phil. Mag.,* Jan. 1926, § 1): it would evidently not be permissible in relation to wood or other materials which exhibit a definite "grain."

38. Fig. 11 gives some results, due to Kirkaldy (Experiments on the Mechanical Properties of Steel by a Committee of Civil Engineers, London, 1868 and 1870), which have been interpreted in this manner; they relate to tests made on long rods in tension. It will be seen that the stress and strain are very closely proportional—*i.e.,* that Hooke's law is satisfied—up to a definite limit for each material which represents a considerable stress but a very small extension (less than ½%). This limit is termed the "limit of proportionality" for stress of the type considered. After it has been passed, the strain increases at a much greater rate in relation to the stress; moreover, as we shall see later, the strain does not disappear when the load is removed, so that the elasticity of the material, as well as the proportionality of stress to strain, has broken down. Therefore, in real materials, the second assumption (b) of the mathematical theory is satisfied only within the limits of proportionality: if these are exceeded, we may no longer assume that the stresses are distributed in accordance with our calculations.

39. A restriction is thus imposed upon the application of mathematical theory. But its practical utility is not seriously affected, for the reason that *stresses which would produce elastic failure should be avoided in design:* they would evidently involve permanent distortion of the member concerned, and in most cases they would be liable to cause actual rupture of the material. It is a general rule of design that stresses must not be allowed to exceed the "limits of proportionality" for the material concerned; so we may say that *assumption (b) will be satisfied by actual materials, within the permissible range of stress.*

It follows that assumption (c) will also be satisfied, since, as we have just seen, the permissible range of stress corresponds to a very small permissible range of strain. To sum up:—Unless we are concerned to know the distribution of stress in such detail that the actual structure of our material is a contributory factor, we may rely on the mathematical theory to predict either (1) the distortion or (2) the stresses which will be produced by specified loads, up to that point at which the strains first cease to be purely elastic. After this point is reached, we are less concerned to know the precise distribution of stress, because we know in advance that the stresses will be unsafe.

But a problem of fundamental importance still remains to be examined, in that the mathematical theory, of itself, affords no answer to the general question, whether specified forces will involve stresses that are safe. Curves of the type of fig. 11, derived from tensile tests, will of course give the required information in relation to members which have to withstand pure tension; but they will not supply adequate data for the design, *e.g.,* of a crank subjected to combined twist and bending, since this, as we have seen (§ 33), involves a state of *compound stress.*

The Question of Elastic Failure.—40. The circumstances which determine failure of elasticity in real materials, when the state of stress predicted by theory is of the most general type (involving three unequal principal stresses) have been a subject of much controversy. At the outset we observe that this is one of the exceptional cases, mentioned earlier, in which mathematical theory, with its fundamental assumption of continuity, ceases to give an adequate account of the real state of affairs. For whatever may be the factors affecting strength, they must depend upon the structure of the material, which is not in fact uniform or continuous. Failure will commence at some point of greatest weakness, and will be determined, not by the general distribution of stress, considered statistically, but by the actual state of stress at that point.

Thus our mathematical concept of stress, and the calculations which are based upon it, break down as applied to the "problem of elastic failure," which strictly falls within the province of the physicist rather than the engineer. On the other hand, we have no alternative method of calculation, and some basis for design must be laid down, even though it may not be strictly logical. What is attempted is to find rules whereby, when the stress-distribution has been calculated by the mathematical theory, it may be examined to determine whether the stresses fall within the elastic limit. We suppose that our material has been tested under simple conditions (*e.g.,* in tension, where the state of stress is as illustrated in diagram A of fig. 1), and that its limits of proportionality have been ascertained. We are confronted, in the general problem, with the state of stress which is illustrated by diagram D of the same figure; and we seek a criterion which shall determine limits of proportionality for this state. The evidence for the criterion will be experimental, but it must be interpreted in accordance with "statistical" ideas, which have no strict validity; so it is not surprising that general agreement on a definite criterion has not in fact been attained.

Alternative Theories.—41. Lamé, followed by Rankine, adopted a *Maximum Stress Theory,* according to which the criterion of elastic failure is p_1, the (numerically) greatest of the principal stresses. Let f be the limit of proportionality as measured in a simple tensile test: then, according to the theory, failure occurs if

$$p_1 \geqq f,$$

and p_2 and p_3 have no effect. In particular, f is the limiting value of the hydrostatic pressure which can be sustained without permanent distortion of the material.

Experiment contradicts this conclusion, for it is found that much greater pressures can be sustained[1]: moreover, the theory is at variance with results obtained in torsion tests, where the material is subjected to simple shear (§ 31). The criterion is no longer accepted, except as a working rule for design in brittle materials, such as cast iron.

42. The *Maximum Stress Theory,* proposed by Poncelet and St. Venant, asserts that extension, rather than stress, is the deciding factor. If e_1 is the (numerically) greatest of the three principal strains, it asserts that failure will occur if

$$e_1 \geqq e,$$

where e is the limiting strain in a simple tensile test. This criterion, in virtue of (18), may be written in the equivalent form

$$p_1 - \sigma(p_2 + p_3) \geqq f,$$

which shows that all three of the principal stresses are involved.

This theory, too, is discredited by the evidence which has been cited. Wehage, in 1888, found the criterion to be at variance with results for wrought iron subjected to equal tensions in two directions at right angles.

43. The *Maximum Shear Theory* was first proposed by Coulomb. It asserts that the greatest shearing stress, or (what is the same thing) the algebraic difference between the greatest and least of the principal stresses, is the deciding factor. Thus, if p_1, p_2, p_3 are the principal stresses, and if

$$p_1 > p_2 > p_3,$$

the theory asserts that failure will occur if

$$p_1 - p_3 \geqq f,$$

where f has the same meaning as before.

Tests made on ductile materials (low-carbon steel, copper, brass) lend considerable support to this theory. In the experiments of J. J. Guest (Phil. Mag., July, 1900), somewhat inconclusive evidence was obtained from non-ferrous materials, but the results for steel were in close accord with the "stress-difference" criterion, which is generally accepted to-day as a basis for design in ductile materials. It is commonly known as "Guest's law."

From a theoretical standpoint, however, Guest's law is open to the objection that it indicates no limit to the strength of a

[1]Extension of the theory by the assumption of different limits for tension and compression (the latter determined by means of a compression test) only partially removes this difficulty.

material when the state of stress is that known as "hydrostatic tension,"—*i.e.*, when the principal stresses are all equal and positive. Practical difficulties have so far prevented the imposition of this stress in an actual experiment, but it is impossible to believe that elastic failure could never occur. Moreover, it is known that the limits of proportionality for tension and compression are not always equal, as the law would suggest. In relation to materials like cast iron, the criterion certainly requires modification: we shall consider that modification which has been proposed by O. Mohr. (*Zeitschr. des Vereines Deutscher Ingenieure,* Bd. 44, 1900.)

44. *Mohr's theory* rests on an hypothesis regarding the nature, or inner mechanism, of elastic failure. Just as two bodies having rough surfaces in contact will slip over one another if a force is applied which is sufficient to overcome the resistance of friction, so two parts of the same body, separated by an imaginary surface, are imagined to slip when the tangential stress at this surface attains a certain limiting value. Irreversible or "non-elastic" strain is regarded as the resultant effect of such slips occurring on a large number of planes in the material. And just as the resistance of friction, in the first case, depends on the pressure between the two bodies at their surface of contact, so it is contemplated that the limiting intensity of the tangential stress may depend upon the normal stress with which it is compounded. Mohr's theory seeks to determine, by means of simple tests, the general nature of this dependence.

According to the view just stated, if two planes in the material are subjected to the same normal stress, slipping will occur first on that plane which is subjected, in addition, to the greater tangential stress. Therefore, in Mohr's circle diagram (fig. 4), the state of stress on that plane at which elastic failure originates will be given by some point on the outer circle *BAX*, which is determined by the greatest and least of the principal stresses.

Let f_t denote the limit of proportionality for the material, as determined by a simple tensile test. Then it is known that elastic failure can occur under a state of stress defined by principal stresses f_t, O, O, and the normal and tangential components of stress for that surface at which failure originates will be given, for this state, by some point on the circle *OAB* in fig. 12. Similarly, if f_c is the limit of proportionality as determined by a test of the material in simple compression (where the principal stresses are $-f_c$, O, O), we know that the component stresses on the surface at which failure originates will be given by some point on the circle *OCD* of the same diagram. It is not necessary to draw more than one half of each circle, because the sign of the tangential stress, on the hypothesis stated, will not affect the question of failure.

Now a circle could be drawn in the diagram to represent any other state of stress for which the limit of proportionality had been determined: all that is needed is a knowledge of the greatest and least of the principal stresses, to fix the ends of its horizontal diameter. According to Mohr's hypothesis, circles drawn in this

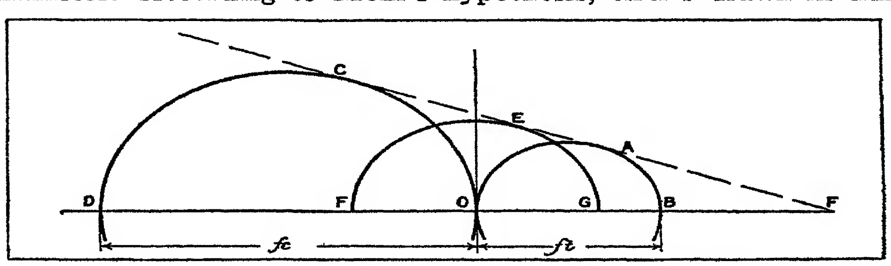


FIG. 12.—MOHR'S THEORY OF ELASTIC FAILURE

way for all conceivable tests would be touched by an enveloping curve, such as the dotted curve *CEA* in fig. 12; and this curve will represent the relation of tangential to normal stress which is the real criterion of elastic failure. For practical purposes the form of *CEA* may be determined by drawing only a few circles: for example, in addition to the tensile and compressive tests which have been considered already, we might carry out a test of the material in torsion (*i.e.*, in simple shear), and so obtain a circle centred at the origin, as illustrated by *FEG* in fig. 12. If the stress-difference criterion were correct, we should find that all three circles had the same diameter, so that the form of *CEA* would became a straight line parallel to *DOB*.

Mohr's theory is a logical development of assumptions which are certainly reasonable. Moreover, it offers a way of escape from the difficulties, mentioned above, in regard to the permissible limits for "hydrostatic" tension and compression; for there is no reason why the enveloping curve should not meet the horizontal axis at some point *F* which (regarded as a circle of zero diameter) represents a limiting hydrostatic tension of finite intensity, whereas on the compression side it may very well cut the axis at infinity. These questions are left to be settled by experiment.

Strain-energy Theories.—45. A criterion of quite another type was suggested by Beltrami in 1885 (Roma. Acc. Lincei Rend. 1885; Math. Annalen, 1903), and more recently by B. P. Haigh (Brit. Ass. *Reports,* 1919 and 1921): it is based on the assumption that any definite volume of material has only a limited capacity for absorbing and storing energy in the form of elastic strain. In isotropic material, the energy stored per unit volume in a state of stress defined by p_1, p_2, p_3 is

$$W=\frac{1}{2E}\left[p_1^2+p_2^2+p_3^2-2\sigma(p_2p_3+p_3p_1+p_1p_2)\right], \qquad (34)$$

and according to Beltrami's theory, failure will occur if

$$W \geqq C^2,$$

where C is a physical constant of the material.

On this basis, the limits for "hydrostatic" tension and compression will evidently be identical, and this fact constitutes an objection which has been urged already, in relation to other theories.

46. Hüber, followed by Hencky (*Zeitschr. f. Ang. Math. u. Mech.,* 1924), has proposed a modified energy criterion, in which that part of W which corresponds to change of volume (as opposed to change of form) is neglected. This procedure is equivalent to the assumption of an infinite bulk-modulus,—that is (§ 28) to the assumption that σ has the value $\frac{1}{2}$: inserting this value in (34), we have the modified criterion, that elastic failure will occur if

$$\frac{1}{4E}\left[(p_1-p_2)^2+(p_2-p_3)^2+(p_3-p_1)^2\right] \geqq C^2, \qquad (35)$$

where C has the same value as before.

No limit is now imposed on the resistance of the material either to hydrostatic tension or compression, and hence one difficulty (in theory) still remains. The criterion is found to accord closely with the results of experiment, within the ranges of stress which have been imposed.

TESTING OF MATERIALS

47. The second branch of our subject—that known as "testing of materials"—is concerned with those properties of real materials which determine their value to the engineer. His most important requirements are rigidity, which demands a knowledge of the elastic constants, and strength, which requires that the criterion of elastic failure shall be expressed in exact numerical form; but he desires in addition that his materials shall possess qualities, such as hardness and tenacity (or "toughness"), which are more difficult to define with precision, because they relate to behaviour in that range of stress and strain wherein Hooke's Law, and hence the mathematical theory of elasticity, do not apply.

Stress-strain Diagrams.—48. The customary procedure for determining elastic constants is to plot diagrams of the type exemplified by fig. 11, showing the relation of stress to strain. Young's modulus (E) is generally obtained by subjecting a long rod to tension, and measuring the consequent increase in the distance between two definite marks. The stress is calculated, in accordance with § 29, as the ratio (total load)/(area of cross-section), and the extension as the ratio (increase of length between marks)/(original length between marks). To find the modulus of rigidity (μ), it is usual to subject a circular rod to torsion, and to interpret the results in accordance with the mathematical solution of this problem (§ 31), whereby the shear stress

(q) at the outer surface can be calculated in terms of the twisting couple, and the shear strain (θ) in terms of the rotation, relative to one another, of two cross-sections separated by a known length. Knowing E and μ, we can, theoretically, deduce any other of the elastic constants by the formulae of § 28. But special methods are often employed to determine particular constants directly: thus, Poisson's Ratio 6, or the "bulk modulus" k, can be found by tests which depend upon the mathematical solution for uniform bending, or for a closed tube subjected to internal pressure (§ 36).

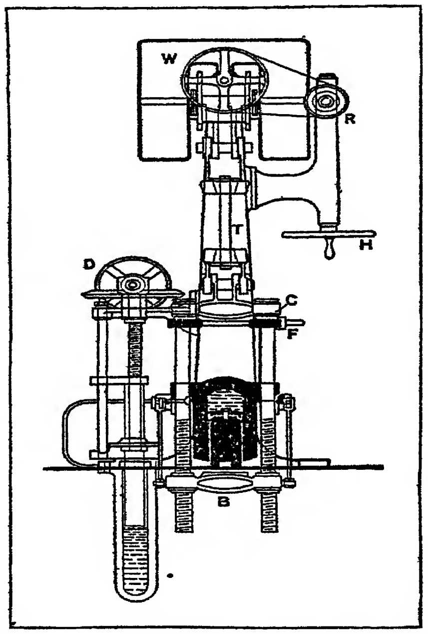


FIG 13.—SINGLE-LEVER TESTING MACHINE

In all cases, when the diagram has been constructed, the relevent elastic constant can be deduced as the ratio of stress to strain within the range for which these quantities are proportional. The extent of this range is also determined by the test, and it provides a part of the information required to fix the criterion of elastic failure (*see* §§ 41–46). But, for reasons which we have indicated, the whole diagram (up to the point of ultimate fracture) is important: thus it is essential that we should be able, in these tests, to apply a measured load through a considerable distance.

Testing Machines.[1]—49. When a material is to be tested in simple tension, and when samples are available in the form of thin wires, the stress may be applied directly by means of suspended weights: for pieces of larger section some mechanical means for multiplying force is required. In large testing machines, the load is usually applied by hydraulic pressure acting on a plunger to which one end of the specimen is secured, and it is measured by connecting to the other end a lever, or system of levers, provided with adjustable weights. Provision is generally

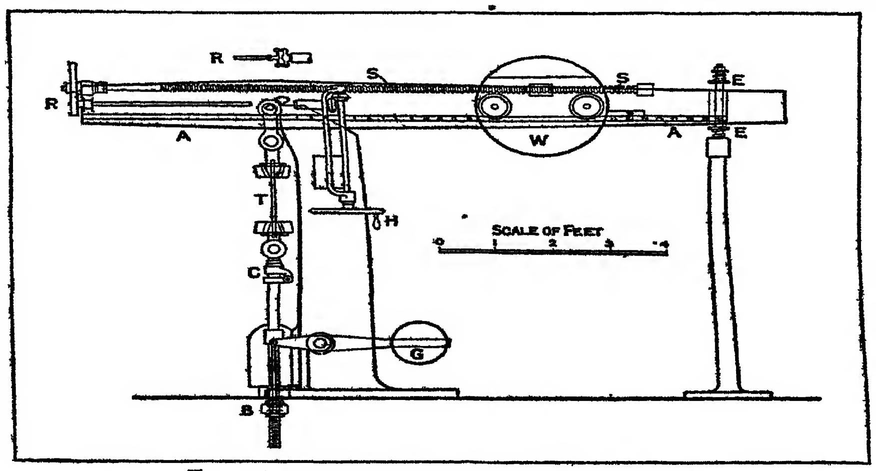


FIG. 14.—SINGLE-LEVER TESTING MACHINE

made for subjecting a specimen either to simple tension, simple compression, bending or torsion.

Figs. 13 and 14 show a form of single-lever testing machine designed by J. H. Wicksteed (*Proc. Inst. Mech. Eng.*, 1882); the machine shown exerts a maximum force of 30 tons, but 100 tons or more are exerted by similar machines in common use. AA is the lever, on which there is a graduated scale. The stress on the Test-piece is measured by a weight W which can be moved through a measured distance along AA by a handwheel H connected with gearing SS. The Hooke shaft R is shown in a separate sketch in fig. 14. The upper end of the sample is gripped in a holder which hangs from a knife edge 3 inches from the fulcrum of the lever; the lower end is gripped in a similar holder which is jointed to a cross-head C, connected by adjustable screws (to provide for specimens of different lengths) to a lower cross-head B, on which the hydraulic plunger exerts its thrust. G is a counterpoise which pushes up the plunger when the water is allowed to escape. In this machine the hydraulic pressure is applied by means of an auxiliary plunger Q of small diameter. Q is driven by a belt on pulley D.

Pressure being admitted to the main plunger, a load is imposed upon the specimen, and the weight W is then run out along the lever until this just "floats" between the stops EE. The load (and hence the stress) can thus be determined, and it remains to measure the accompanying strain.

Extensometers.—50. It will be appreciated that this last requirement calls for very precise apparatus. In iron or steel, the extension produced by a stress of 1 ton per sq.in. is about $\frac{1}{13,000}$, and elastic failure occurs at an extension of perhaps $\frac{1}{1,000}$: thus, it the extension of an 8 inch "gauge length" is to be measured, it is desirable that this shall be read to about $\frac{1}{50,000}$ inch when Young's modulus or the extent of the elastic range are under examination. Measurements made on one side of the specimen only are liable to be in error on account of bending caused by slight eccentricity of loading: accordingly, it is best to measure the relative displacement of two pieces attached in such a manner as to share equally in the strain on both sides.

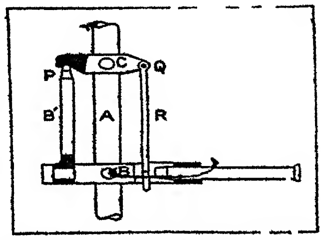
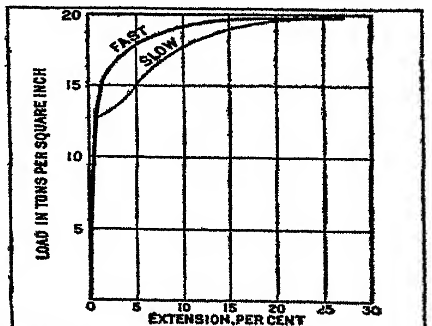


FIG. 15.—EWING EXTENSOMETER

The extensometer of J. A. Ewing is illustrated (diagrammatically) by fig. 15. Two clips B and C are attached to the specimen, each by means of a pair of opposed screws. Between B and C is a rod B', hinged to B and fitting into a spherical recess in C. A bar R hangs from C by a hinge Q, and carries a mark which is read by a microscope attached to B. Thus, as the specimen stretches (B' remaining of constant length), the bar R is pulled up relatively to the microscope, and the amount of the movement is measured by a micrometer scale in the eye-piece. Calibration is effected by means of a micrometer screw attached as indicated at B.

Strain Beyond the Elastic Limit: Influence of Time.—51. Within the region of "plastic" distortion (*i.e.*, where the stress and strain are not directly proportional) it is found that the behaviour of a metal is largely influenced by the *rate* at which the load is increased; the full strain corresponding to a given load is reached only after a perceptible time. Fig. 16 gives some results obtained by Ewing (J. A. Ewing, *Strength of Materials*, p 42, 1914), from tensile tests of soft iron wire. The "fast" loading caused rupture in 4 minutes: the "slow" loading took 5,000 times as long. When a tensile load, of amount exceeding the elastic limit, is applied and then kept constant, the specimen is observed to extend at first rapidly and then more slowly. In general it appears that the slow extension comes ultimately to an end; but when the applied load is nearly equal to that which would immediately break the specimen, the extension, after slowing down, quickens again and continues until rupture occurs. If, on the other hand, the specimen is subjected to an *extension* which is maintained constant, it is found that the load required to maintain that extension gradually diminishes.

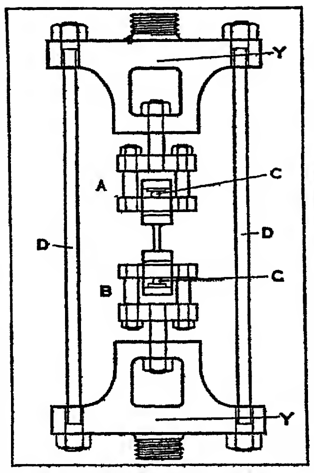


FROM J. H. EWING, "STRENGTH OF MATERIALS" (UNIVERSITY PRESS, CAMBRIDGE)
FIG. 16.—INFLUENCE OF RATE OF LOADING

"Yield."—52. Special interest attaches, for materials such as wrought iron and mild steel, to that part of the stress-strain dia-

[1] §§49–56 have been based, by permission, on the article written by Sir J. A. Ewing for the 11th edition of this *Encyclopædia*.

gram which lies just outside the elastic range. Reference to Kirkaldy's diagrams (fig. 11) shows that a point (called by A. B. W. Kennedy the "yield-point") is reached, soon after the material has ceased to be elastic, at which the extension increases without any corresponding increase of stress. Somewhat later, the extension becomes less rapid and the stress rises at a fairly regular but gradually decreasing rate. If a lever type of machine is employed, the beam drops when the yield point is reached. Meanwhile the specimen is seen to undergo a considerable change: if scale previously adhered to its surface, this is observed to flake off, in lines inclined at roughly 45° to the direction of pull; if the surface is polished, lines appear on it, having the same direction, which can be recognized by touch as steps or ridges. These lines are known as *Lüders' lines* (W. Lüders, *Dingler's Polytech. Journ.*, vol. 155 [1860], p. 18): their occurrence may be used to determine, without the use of an extensometer, the yield point of a material.



FROM "PROCEEDINGS OF THE ROYAL SOCIETY"

FIG. 17.—APPARATUS EMPLOYED BY ROBERTSON AND COOK

Researches by A. Robertson and G. Cook (*Proc. R.S.* [A], vol. 88, 1913) have shown that the phenomenon of "yield," thus revealed by early diagrams, is much more complex than those diagrams would suggest, and of the first importance from the practical standpoint. Realizing that its effects would be masked by the inertia of the testing machine as ordinarily employed, these investigators employed the device which is illustrated by fig. 17. Two long rods *DD* were arranged in parallel with the specimen, so as to share in taking any load applied to the end yokes, *YY*. The loads taken by these rods could be deduced (from a previous calibration) by measuring the elastic strains to which they were subjected: thus, when the total load applied to the yokes was known, the load in the specimen could be deduced. Yield of the specimen merely shifted a greater part of the total load on to the rods; and since these, on account of their length, remained elastic, there was no sudden increase in their total extension, and consequently no drop of the beam. Accurately central loading of the specimen was ensured by applying the load through hard steel balls, *CC*, with the aid of special shackles *A*, *B*.

The specimens were of ordinary mild steel, annealed (*see* § 54) to remove any stresses which might have been induced in course of manufacture. The results showed that the stress, on the occurrence of "yield," does not merely remain constant, but actually *drops*, by an amount which may be as high as 36%. The practical importance of this effect is evident, for it means that the material, within the region of "plastic" strain, can adjust itself in such a manner as to relieve any intense concentration of stress which may have occurred within the elastic range. This property, which is of great value in constructional work, is known as *ductility*.

Intermittent Loading: Hardening Effect of Permanent Set.—53. Time has another effect of a different and remarkable kind. If, at some point *a* (fig. 18) in the region of plastic strain, the load is removed, a part of the strain disappears. This part is accordingly termed the "elastic strain": to a close approximation, it is related with the stress by a linear law, the ratio of stress to elastic strain being, so far as can be ascertained, the ordinary elastic constant of the material. If the load is immediately replaced and then increased in the ordinary way, a new yield-point *b* is found at or near the stress previously reached. The full line *bc* in fig. 18 shows the subsequent behaviour of the specimen. If on the other hand, some hours are allowed to elapse before the load is replaced, the new yield point appears, not at *b*, but at a higher stress *d*. Fracture occurs (at *e*, fig. 18) under a higher load than before, and at a smaller total extension: we say that a process of *hardening* has been going on during the interval of rest.

A similar and even more marked hardening is found to occur when the load, instead of being removed and replaced, is maintained constant for some hours. When loading is resumed, the yield-point is found to be raised very considerably. Fig. 19 exhibits experiments of this kind, made by J. A. Ewing on specimens of annealed iron wire: *ab* shows the result of continuing to load after an interval of 5 minutes, and *acd* after an interval of 45½ hours. (J. A. Ewing, *Proc. R.S.*, 1880.)

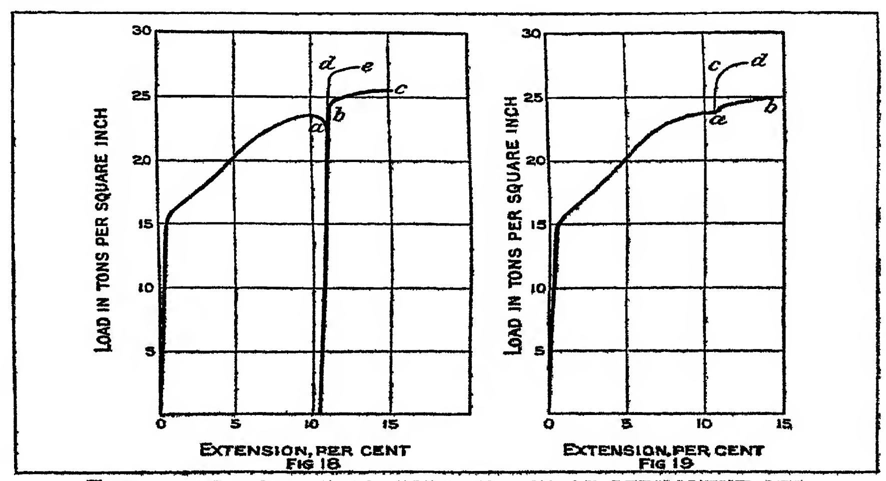
Annealing.—54. This hardening effect of plastic strain is of great practical importance. When a hole is punched in a plate, the material round its edge is severely distorted by shear, and the consequent hardening of this material is accompanied by a serious decrease in ductility. Consequently, if the plate is strained by tension, concentration of stress, resulting in the formation of cracks, may occur at the edge of the hole. This bad effect of punching disappears when a narrow ring of material, immediately surrounding the hole, is removed by a cutting tool.

The hardening effect can also be removed by the process of *annealing*, that is, by heating to redness and cooling slowly. This process is very generally employed in practice, for relieving internal stresses caused by the processes of manufacture.

Recovery of Elasticity.—55. Although the yield point may be raised by overstrain, as described above, the elasticity of the material is found to be impaired. Only within narrow limits, if at all, is stress proportional to strain during the process of reloading. But a sufficiently long rest will restore the elasticity, and after weeks or months the metal is found to be elastic up to a point which may be much higher than the original elastic limit.

Experiments by J. Muir (*Phil. Trans. R.S.*, vol. 193, 1900) have shown that temperature has an important influence on the rate of this "recovery of elasticity." In iron and steel, complete recovery can be produced in a few minutes by dipping the overstrained specimen into boiling water.

When a piece of iron or steel, after being overstrained in tension, is subjected to a compressive load, the strain is not found to be proportional to stress unless recovery has been effected by rest or heating. After recovery, the elastic limit for compression is lower than it would be in the normal state; but Muir's experiments show that the reduction is less than the amount by which the elastic limit for tension has been raised. That is to say, the general effect of strain-hardening followed by recovery is to widen the total range of stress within which stress and strain are proportional.



FIGS. 18 AND 19.—HARDENING EFFECT OF PERMANENT SET

Hysteresis.—56. We may summarize this account of the behaviour of metals within the range of "plastic" strain by saying that the strain in this range is no longer (as in Hooke's law) uniquely determined by the stress, but depends upon the previous "stress-history." This phenomenon is termed "*hysteresis*." When the stress on a specimen fluctuates in a regular manner between two fixed limits, the stress-strain diagram assumes the form of a closed figure, which is called a "hysteresis loop."

Fig. 20 shows hysteresis loops for a steel specimen exposed to three different cycles of stress; the sequence of operations is

Material	Results from tensile test								Fatigue properties
	Young's Modulus (tons per sq. in.)	Poisson's ratio	Limit of proportionality (tons per sq. in.)	Stress at "yield" (tons per sq. in.)	Stress at fracture (tons per sq. in.)	Elongation, %	Reduction of area, %	Brinell hardness number	Endurance limit (tons per sq. in.)
Mild steel (0·02% carbon)	13,400	0·3	7·2	8·5	19	48·3	76	69	±11·6
Medium carbon steel (0·37% carbon), annealed	do	do	16·3	16·9	31·3	32	49	131	±13·0
Ditto., quenched and tempered	do	do	29	30·8	47	22	56	205	±22·8
Nickel-chrome steel, quenched and tempered	do	do	97·8	—	125·5	7 5	31 5	510	±48·7
Steel casting (0·32% carbon)	do	do	8·9	15	34	26	34	141	±13·5
Drawn copper	—	0·35	—	—	18·3	26	48	—	Less than ± 7·75
Hard-drawn brass	about 5,000	0·33	—	—	26·8	40	73	—	Less than ± 8·9
Duralumin, heat-treated	4,900	—	—	—	22·8	29	47	100	± 5·4
Ditto, annealed	4,800	—	—	—	11·2	25	61	50	± 4·8

indicated by the arrows. It will be seen that the area of the loop increases with the range of stress. This area may be interpreted as measuring the work done in performing the cycle of operations: if the strain had been wholly elastic, the area of the loop would have been *nil*, because the work done in stretching would have been recovered during the process of unloading, but in the plastic range more work is done in stretching than is subsequently recovered. The difference, of course, is absorbed by the specimen or transformed into heat.

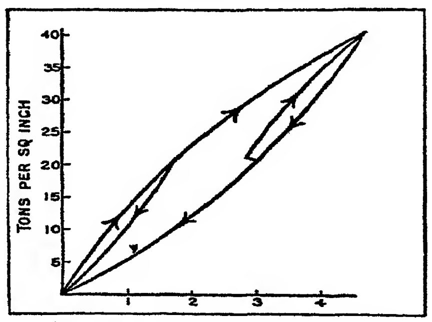


FIG. 20.—HYSTERESIS LOOPS

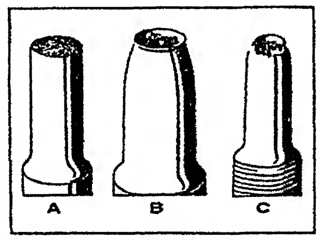
Elongation and Reduction of Area.—57. Useful information in regard to ductility is afforded by the *elongation* of a specimen tested in tension—that is, the total extension of the specimen at the instant of fracture. Barba (*Mem. Soc. des Ing. Civ.*, 1880) has shown that this quantity depends upon the form of the specimen, so that geometrical similarity must be maintained if strictly comparable results are to be obtained from specimens of different sizes. Unfortunately, the practice of different countries as regards the standardization of test pieces does not yet satisfy this condition.

Another quantity which serves as a convenient measure of ductility is the *reduction of area*—that is, the decrease in the cross-sectional area of the specimen after fracture, expressed as a percentage of the original area. This quantity is less dependent than elongation on the geometrical form of the specimen but it is difficult to measure accurately.

Fracture by Tension.—58. The ultimate stages of a tension test—that is, the circumstances which determine the elongation and reduction of area—are evidently governed by the stress-strain relations in plastic material, of which little is understood. When a bar of uniform section is pulled, the extension is at first distributed fairly uniformly over the whole gauge length. But just before the bar breaks, a large additional extension occurs near the place of rupture, and the section is much more contracted there than in other parts, so that the specimen forms a "waist." Fig. 21 illustrates this point; it is taken from a photograph of a broken specimen of mild steel, which had a uniform diameter before the test.

FIG. 21.—MILD STEEL SPECIMEN FRACTURES BY TENSION

It appears that the material, just before fracture, is in an unstable state of stress. Any local contraction of area will cause an increase of stress in that region, and this in turn will cause further plastic distortion, or "flow." On the other hand, the hardening effect of plastic strain operates in the reverse direction, tending to increase the resistance to flow. It is probable that this second effect predominates in the earlier stages of the test, and so maintains stability; for it seems clear that the first effect, once it predominates, must result in final rupture. The notion of instability seems to explain the observed fact, that the ultimate stress (at fracture) is largely dependent upon the form of the test specimen.

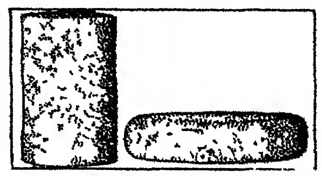


FROM H J GOUGH, 'THE FATIGUE OF METALS' (BENN)

FIG. 22.—STATIC TENSILE

Rupture may occur by direct separation over a surface which is nearly plane and perpendicular to the direction of the pull: such fractures are characteristic of hard steels and other non-ductile materials. But in ductile materials, which break at a "waist," the fractured specimen generally reveals a ring-shaped crater on one side of the break and a truncated cone on the other (fig. 22): rupture has occurred by shearing on the outer (inclined) surface and by direct separation in the central region, where the fracture is approximately plane.

Fracture by Compression.—59. In compression tests of ductile material, such as mild steel, the process of "flow" may continue indefinitely, as indicated by fig. 23. There is here no possibility of instability (if the specimen is made short, to avoid buckling in the manner of long columns), since the flow results in an increase of cross-section, which tends to reduce the stress. Brittle materials fail by shearing on inclined planes, after the manner of fig. 24. These planes are nearly, but not exactly, coincident with the planes of maximum shear. It appears that a normal component of stress on a plane may increase the resistance to shear on that plane, in the manner contemplated by Mohr (§ 44).



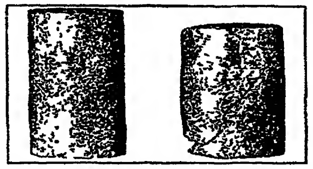
FROM TIMOSHENKO AND LESSELS, "APPLIED ELASTICITY"

FIG 23.—COMPRESSION FAILURE OF LOW-CARBON STEEL

FATIGUE

60. A question of great interest, both scientific and practical, is the effect of stresses which fluctuate repeatedly between definite limits. Hodgkinson, in 1837, first drew attention to this problem. At that time, bridges of masonry were being replaced on an extensive scale by bridges of wrought iron, and engineers who

appreciated the significance of Hodgkinson's experiments realized that the properties of the new material were very imperfectly understood. A commission was appointed to consider the application of iron to railway structures, its report (1849) described experiments which indicated clearly (1) that failure can result from repetitions of a load less than the ultimate static load, and (2) that such failure is *not* caused by deterioration of the material with time, if the ultimate static load may be taken as an indication of quality.

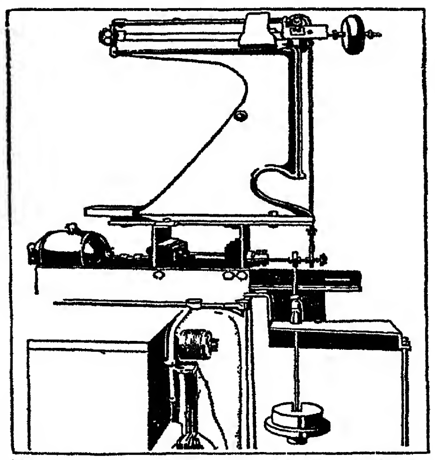


FROM TIMOSHENKO AND LESSELS, "APPLIED ELASTICITY"
FIG. 24.—COMPRESSION FAILURE OF CAST IRON

Fracture produced by a large number of repetitions of stress is generally described as "fracture by fatigue." The classical researches on the subject are those of A. Wöhler, who tested iron and steel under direct tension, torsion and bending, and who paid, for the first time, strict attention to the magnitudes of the *local stresses* involved. Wöhler's experiments showed that a stress well below the ultimate strength of a material (as measured in an ordinary tension test) will suffice to produce fracture if it be often enough removed and restored, or even alternated with a smaller load of the same kind; the smaller the range through which the stress is varied, the greater is the number of repetitions (or stress-cycles) which a specimen can endure.[1]

These investigations have been continued by many other workers, and the literature bearing on the subject of fatigue is now very extensive Only the merest outline can be given here: the reader is referred to a very clear and complete account by H. J. Gough. *The Fatigue of Metals* (1924)

Testing Machines.—61. Many distinct types of machine have been devised for applying fluctuating stresses. Perhaps the most important is Wöhler's "rotating bar" machine, which (in the modified form employed at the National Physical Laboratory, England) is illustrated in fig. 25 The specimen, a solid or tubular rod, is rotated by an electric motor (as in a lathe) at speeds up to 2,400 r.p m. It is subjected to equal up-and-down forces, applied through ball bearings, at two points in its length, by a small single-lever testing machine and by dead weights. Thus it is exposed, over the greater part of its length, to a uniform bending moment; and since the plane of this bending moment rotates in relation to the specimen, the stress at any point in a cross-section fluctuates between positive and negative values during each revolution. Within the elastic limit, the stresses can be calculated in accordance with § 30.



FROM H J GOUGH, "THE FATIGUE OF METALS" (BENN)
FIG. 25.—WOHLER MACHINE

A modified form of this machine, employed by T. E. Stanton and R. Batson (*Brit. Ass. Report*, 1916) enables torsional stresses to be superposed.

"Specific Stress" and "Specific Strain."—62. It is important to distinguish between the conditions imposed by different machines, because these largely influence the behaviour of the material. Thus the machine just described applies a definite bending-moment (that is, practically speaking, a definite stress), independent of the strains which the material may undergo; we describe such conditions as *specific stress*. In other machines a definite strain is imposed, independent of the stress-distribution which may result through plastic distortion of the specimen; we describe such conditions as *specific strain*. In other machines, again, the conditions are such that the stress either increases or diminishes as the strain increases.

This variation in the conditions of test has its counterpart in actual practice: thus a connecting-rod is exposed to conditions of specific stress, and the valve springs of an internal combustion engine to conditions of "specific strain."

[1] A. Wöhler, *Zeitschr. f. Bauwesen*, vols. 8–20 (1860–70). An account is given in *Engineering*, vol. 11 (1871).

The Variable Factors in Fatigue. Nomenclature.—63. Even when the stress imposed is the simplest possible,—namely, simple tension,—it is evident that many variable factors are involved. First, the stress may vary between any two limits. Using positive and negative signs to denote tension and compression, we write $p_{max.}$ and $p_{min.}$ for the highest and lowest tensions which are imposed; we term $p_{max.}$ the "upper" or "superior" limit of stress, and $p_{min.}$ the "lower" or "inferior" limit. The "total range of stress" (R), and the "average" or "mean stress" of the cycle (M), are then defined by the relations

$$R = p_{max.} - p_{min}\ ,$$
$$M = \tfrac{1}{2}(p_{max} + p_{min}),$$

and the stress-cycle may be concisely described as the cycle

$$(M \pm \frac{R}{2}).$$

In an "alternating stress" test, M is zero and the stress fluctuates between equal and opposite limits.

Again, the stress may fluctuate between specified limits at different speeds If T is the time (in secs.) taken by one complete stress cycle, the number of cycles per second is given by

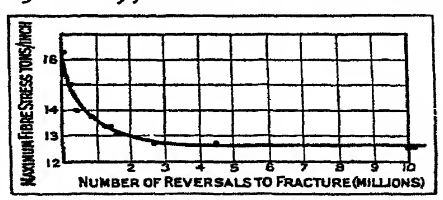
$$n = \frac{1}{T},$$

and is termed the "frequency" of the test.

Further, the stress may fluctuate with time, *during one stress-cycle*, according to any imposed relation. This relation ought always to be specified in describing the results of tests, in order to make the conditions precise; but little information is available at present regarding its importance.

Endurance Tests, and the "S-N Curve."—64. The aim of fatigue tests is to determine, for a definite stress-cycle applied at a definite frequency, the number of cycles which a material can sustain without fracture. This number (N) is termed the *"endurance."*

In a test under alternating stress, the cycles may (subject to the remark at the end of the last paragraph) be taken to be defined by $\frac{R}{2}$, the greatest (numerical) value of the stress S. We seek by experiment to relate S with the endurance N, and the curve which gives this relation is termed an "*S-N* curve." Fig. 26, by T. E. Stanton and J. R. Pannell (*Proc. Inst. Civ. Eng.*, vol. 188, 1911–12), in tests of mild steel, shows typical results. It will be seen that the plotted points lie more or less evenly on a curve which appears to become parallel with the N axis when the number of reversals to fracture is large. The last point on the diagram relates to a specimen which was still unbroken after 10 million reversals of stress. We say that the test has been carried out "on a 10 million reversals basis"; and on this basis we may express the results by saying, either



FROM H. J GOUGH, "THE FATIGUE OF METALS" (BENN)
FIG. 26.—ENDURANCE TESTS

(a) that the endurance limits of stress are ±12·75 tons/sq.in. or
(b) that the limiting range, *for reversed stresses*, is 25.5 tons/sq.in.

65. Evidently, *if the true curve does in fact become horizontal, there is a limiting range of stress below which fracture will not occur for any number of reversals, however large.* It is not possible to decide this question positively, since we can, in practice, impose only a limited number of stress-cycles. (The greatest numbers imposed in any recorded test would appear to be 202 millions: the specimen, tested by J. E. Howard under reversed bending—*Proc. Inter. Assoc. Test. Mat.*, 1909 Congress.—was not broken.) But the weight of evidence appears to show that limiting ranges of stress do exist, and that they can be found, with all the accuracy required for practical purposes, by endurance tests on a 10^7 reversals basis. Gough, who has done much to

See Wissowa, *Religion und Kultus,* 2nd ed., p. 110; H. J. Rose, *Roman Questions of Plutarch* (1924), p. 175.

MATERNITY AND INFANT WELFARE. After the World War all civilized countries realized the importance of decreasing the high death-rate among women at childbirth and among infants under one year of age. In Great Britain there is a considerable body of new legislation intended to supplement welfare agencies and to provide State aid. The Maternity and Child Welfare Act 1918 gives comprehensive powers to local authorities. It consolidates the work commenced in 1906 by the St. Marylebone Health Society. Like nearly every other movement to fight disease, modest experiments by groups of social workers pointed the way to larger State and municipal action.

In 1910 there were 90 infant welfare centres in Great Britain, and by 1914 the number had risen to 400. Owing to the impetus of the War and the Child Welfare Act of 1918, there were in May 1928 no fewer than 1,561 infant welfare centres under the local authorities and 870 voluntary centres, as well as 153 maternity institutions recognized by the Ministry of Health.

The various enactments bearing on the subject are the Factory and Workshops Act of 1901, which endeavours directly to protect the woman who has recently given birth to a child; the Midwives Act of 1902, which laid the foundation of a safe and efficient system of practice by midwives; the Notification of Births Act of 1907 and the extension of the act in 1915, which Miss Margaret Llewelyn Davies described as "nothing less than a welcome by society to each of its newly-born citizens, and a signal of help and a message of hope to every mother in the land." Under this act the father or doctor or midwife must notify the public health authority within 36 hours of the birth of a child. Advice and help, free of charge, are then given by a woman health visitor. The National Health Insurance Act provides a maternity benefit of 40s. for an insured woman or the wife of an insured man.

The Ministry of Health, formerly the Local Government Board, encouraged local authorities to extend and develop their maternity and child welfare services. In a circular letter to local authorities issued in 1914 the board stated that an estimate had been laid before parliament for a grant to be distributed to local authorities and voluntary agencies in respect of institutions or other provision for maternity and child welfare, that more extended and systematic measures than had hitherto been generally adopted were necessary. Sir Arthur Newsholme, in a report on maternal mortality in connection with childbearing, published in 1915, stated that "the present report is intended to draw attention to this unnecessary mortality from childbearing, to stimulate further local inquiry on the subject and to encourage measures which will make the occurrence of illness and disability due to childbearing a much rarer event than at present." His successor, Sir George Newman, 10 years later (1924), in his preface to Dr. Janet Campbell's *Maternal Mortality,* referring to the fact that approximately 3,000 mothers had died each year at childbirth for the previous 10 years, stated: "That is a serious and largely an avoidable loss of life at the time of its highest capacity and in its most fruitful effort."

Administration.—The local authorities carrying out maternity and child welfare schemes are the county councils, county borough councils and the councils of certain of the larger county districts—as a general rule those having a population of more than 20,000. These are in the main the authorities which adopted the Notification of Births Act referred to above, under which some work for mothers and babies was already being done before the passing of the act of 1918. The regulations, under which a grant is payable by the Exchequer of 50% of the approved net expenditure of local authorities, set out the services which may and should be comprised in a maternity and child welfare scheme, and from them the scope and content of the services may readily be understood. 1. The salaries and expenses of inspectors of midwives and of health visitors and nurses engaged in maternity and child welfare work; 2. The provision of a midwife for necessitous women and for areas insufficiently supplied with this service; 3. The provision, for necessitous women, of a doctor for illness connected with pregnancy and for aid during the period of confinement; 4. The expenses of a centre, *i.e.,* an institution for providing medical supervision and advice for expectant and nursing mothers and for children under five years of age, and medical treatment at the centre for cases needing it; 5. Arrangements for instruction in the general hygiene of maternity and childhood; 6. Hospital treatment for complicated cases of confinement and for children under five years of age found to need in-patient treatment; 7. The cost of food certified as being necessary to expectant and nursing mothers and for children where the case is necessitous; 8. Expenses of crèches and day nurseries and of other arrangements for attending to the health of children under five years of age whose mothers go out to work; 9. Accommodation in convalescent homes for nursing mothers and for children; 10. The provision of homes and other arrangements for attending to the health of children under five years of age of widowed, deserted and unmarried mothers; 11. Experimental work in relation to maternity and child welfare work; 12. Contribution by a local authority to voluntary institutions. Exchequer grants on the same scale are also paid to voluntary agencies which carry out certain services to the satisfaction of the Minister of Health.

The expenditure on maternity and child welfare services provided by local authorities for the year 1927–28 was upwards of £1,500,000, in addition to which Exchequer grants amounting to over £217,000 were made to voluntary agencies. If to these figures is added nearly £2,000,000 paid in maternity benefit under the national health insurance scheme, a total of nearly £4,000,000 is spent each year on these services, without taking account of the expenditure out of local rates, or of the voluntary agencies, or of other benefits paid to women during pregnancy from health insurance funds or of the voluntary hospital services.

Infant and Maternal Mortality.—The services given at the centres by both lay and professional workers helped to secure the reduction of the infant mortality rate from 154 per 1,000 births in 1900 to about 70 per 1,000 births in 1927. This gratifying result means that (calculated on the average infant mortality of 1901–10) there was in 1927 a further saving of some 40,000 infant lives. "It also implies a better physical condition in children from one to five years of age, and a more enlightened understanding of personal and public hygiene" (Sir George Newman). While this saving of infant lives is all to the good, it is disturbing to find on an analysis of the statistics that the reduction in the infant mortality rate has occurred almost entirely subsequent to the first few weeks of life and that the death-rate of infants up to the age of four weeks has remained almost stationary, being 32 per 1,000 births in 1927 as against 40 births for 1906–10.

So, too, in the case of maternal mortality, notwithstanding that Sir Arthur Newsholme reported in 1915 that "800 mothers die each year in England and Wales as the result of childbearing whose lives would be saved if the experience of the rest of England and Wales were as favourable as London," and that there would be a further saving of 1,100 lives of mothers secured annually in England and Wales if puerperal fever were to be eliminated "as it has been substantially from the experience of many lying-in hospitals." Dr. Janet Campbell, 10 years later, writes that "avoidable maternal deaths are a matter of everyday occurrence," and that "puerperal infection leads to more deaths and more injury than any other complication of childbearing."

It has been shown that the mortality rate of very young babies is nearly as high as it was early in the century. On examining the statistical returns of maternal mortality as published by the registrar general it is seen that while the death-rate of mothers at childbirth was 5 per 1,000 births for the period 1906–10, it was 4·11 per 1,000 births in 1927.

Here then is the problem. Improvements in general sanitation and public health services, a better education in public and personal hygiene, the maternity and child welfare services, the services provided under the national health insurance scheme, have had no visible effect upon the vital statistics relating to childbearing. Comparing the period 1906–10 with the year 1927—*i.e.,* the period prior to the establishment and development of maternity and child welfare services by the local authorities with the latest complete figures available—it is seen that taking the 1906–10 period as 100, the relative mortality rates provisionally ascer-

tained for 1927 are:—

Maternal mortality	82·2 %
Infants under four weeks	80·0
Infants from four weeks to one year	49·35

According to Dr. Janet Campbell, the death of the mother is often followed by the death of the baby and "by the impaired health and nutrition of the remaining children."

Disability Among Married Women.—It has been pointed out that the mortality returns "reveal only a part of the total damage and disability, and that an incalculable amount of unreported and often untreated injury and ill-health results from pregnancy and labour." Statistics relating to the comparatively heavy incidence of sickness amongst married women were presented to the royal commission on national health insurance which reported in March 1926. The Government actuary reported that an urgent matter is the excess of the claims of married over unmarried women. At the important ages, 20–25, 25–30 and 30–35, the married woman's rates of sickness represent the following percentages of those of the unmarried class:

Ages	*1921* %	*1922* %	*1923* %
20–25	242	284	299
25–30	174	198	242
30–35	158	171	198

The majority report of the royal commission recommended the provision of improved maternity services "as and when funds are available to meet the cost." The minority report, however, declared that "the high maternal death-rate and the great amount of sickness amongst mothers clearly prove the need of reorganization and extension of maternity work," and recommended that medical benefit under the health insurance scheme should include medical attention at confinement and should be extended to include the wives and dependants of insured men. The provision of more adequate services for women at childbirth is a matter of urgent necessity. "If a woman can rely upon securing the services of a careful up-to-date practitioner, or upon the attendance of a well-trained midwife who is able to obtain prompt and competent medical assistance in case of need, nearly all other conditions become of minor importance" (Dr. Janet Campbell).

Effect of Environment.—The development of antenatal services appears to afford the most likely solution to the problem. Regional distribution of the mortality does not point to industrial factors as being the chief causes of deaths. At the same time, it is not without significance that nine of the 10 county boroughs having the highest rates of maternal mortality in the four years 1919–22 were in Lancashire and Yorkshire, and seven of those nine towns, viz., Halifax, Rochdale, Huddersfield, Bury, Oldham, Dewsbury and Blackburn, in the report of 1914–15 are among the county boroughs which exact "the heaviest toll of life from mothers in childbearing." Industrial areas can, however, be found with extremely low rates of mortality; the predominatingly working class district of West Ham actually had in 1919–22 the lowest rate of maternal mortality of all the county boroughs.

The same county borough had the lowest rate among the metropolitan boroughs in 1914. In the counties of Lancashire and Yorkshire it is the practice for a considerable proportion of married women to be employed in the textile mills, and it is difficult to resist the conclusion that the nature of their employment, together with the strain of managing the household and bearing large families, is in no small degree responsible for the unenviable position which the towns occupy and have occupied for so many years. The puerperal death-rate in Wales has always been higher than that in England, and, until recently, than in Scotland. That is probably due, not so much to any special cause peculiar to Wales, as to the fact that, broadly speaking, the whole country is either extremely rural or highly industrial. The services available in most rural areas leaving much to be desired, and the exceedingly hard life associated with the mining industry, must be factors contributing to the high maternal mortality rates disclosed.

An enlightened public opinion would encourage and, where necessary, compel the local authorities to provide the services considered by the experts to be essential. The medical profession has the knowledge; administrators, local and national, are capable of creating the administrative machinery; there is no lack of voluntary helpers; the provision of the necessary finance and the co-operation of mothers are the factors depending upon education.

It may be said, in summing up this vitally important subject, that there are few departments of human life in which greater and more beneficent progress has been made in recent years, as compared with the ignorant and haphazard practice of the past.

Bibliography.—*The International Year Book of Child Care and Protection,* compiled by E. Fuller (1925); *Oeuvre Nationale de l'enfance—Rapport annuel* (Brussels, 1923); *Inter. Record of Child Welfare Work,* No. 1–2 (Brussels, 1921–23) continued as *Bulletin international de la protection de l'enfance* (No. 22) (Brussels, 1924); *Co-opération et prévoyance sociale en Tchécoslovaquie,* ed. A. Klimt (Prague); *The Declaration of Geneva* (in 36 languages) (London); J. M. Campbell, M.D., *Reports on Public Health and Medical Subjects, No. 5: Maternal Mortality;* No. 48: The Protection of Motherhood, Ministry of Health (H.M. Stationery Office, 1924); *Report of the Proceedings of the Third English-speaking Conference on Infant Welfare* (1924); *Annual Report of the Infant Welfare Societies of Chicago* (Chicago). (M. Bon.)

UNITED STATES

In the United States public health work essentially educational in character did not begin until the present century. The great increase in scientific information as to the pathology of disease, together with the development of a public-nursing technique, made possible a preventive programme. Before 1900 public health activities were largely confined to the control of contagious disease and sanitation. Thus, while the first school inspection was begun in Boston in 1894, the first health teaching in connection with the schools was undertaken through the co-operation of the Henry Street Nursing Service in New York in 1902; and the present type of school health programme which seeks to interest the child in the formation of good health habits began to be included in school curricula only about 1918.

The establishment of the first bureau of child hygiene, in New York city in August, 1908, with Dr. S. Josephine Baker as its director, began a new era in the child health programme. In 1910 New York and Louisiana organized divisions of child hygiene in their State departments of health. The U.S. children's bureau created by act of Congress in the spring of 1912 was directed to "investigate and report upon . . . all matters pertaining to the welfare of children and child life among all classes of our people . . . and especially . . . the questions of infant mortality, the birthrate . . . and diseases of children," and under the leadership of Julia C. Lathrop began at once a series of studies of infant mortality, the publication of popular bulletins and co-operation in demonstrations of child health examinations, "baby weeks," etc. By 1920 child hygiene divisions had been established in most of the larger cities and towns and in the departments of health in 28 States. In 1921 the U.S. Maternity and Infancy Act, popularly known as the Sheppard-Towner Act, was passed.

In 1923 two private national organizations, the American Child Hygiene Association and the Child Health Organization of America, united under the presidency of the Hon. Herbert Hoover to form the American Child Health Association. This association has been active in promoting May Day as Child Health Day, and has published an important survey of child health in 86 cities with a population of from 40,000 to 70,000, and many popular bulletins.

The Federal Maternity and Infancy Act authorized for a five-year period, which was extended to a seven-year period in 1927, an annual appropriation of $1,240,000, of which a sum not to exceed $50,000 may be expended by the U.S. children's bureau for administrative purposes and for the investigation of maternal and infant mortality, the balance to be divided among the States accepting the act as follows: $5,000 unmatched to each State, and an additional $5,000 to each State if matched; the balance to be allotted among the several States on the basis of population and granted if matched. National administration of the act was lodged with the children's bureau of the U.S. department of labour; local administration in the States is in the child hygiene or child wel-

fare division of the State agency of health, or, where such a division does not exist, the agency designated by the State. In 1927, 45 States—all except Connecticut, Illinois and Massachusetts—had accepted the benefits of the act and approximately $1,000,000 was being expended by the National Government in subsidies to the States. In 1924 the benefits of the act were made available to the territory of Hawaii, which promptly accepted and matched the funds made available. The 1927 report of the activities undertaken by the States under the terms of this act showed continued progress as old activities spread over a greater territory and new activities were initiated. These had for their objects (1) better infant care through the teaching of mothers; (2) better care for mothers through education as to the need and value of skilled supervision during pregnancy, childbirth and the lying-in period; and (3) more widespread medical and nursing facilities so that adequate maternity and infant supervision would be available. Children's health centres or conferences and prenatal or maternity centres or conferences are everywhere recognized as the best agencies for teaching the hygiene of maternity and infancy. An objective in most of the States is the establishment of permanent, locally-supported centres. Demonstration conferences have been held and intensive pieces of work undertaken by the States when there was evidence of special need. In the main the activities promoted with maternity and infancy funds have been for the benefit of rural communities and smaller cities and towns. State reports of the work during the fiscal year 1926–27 show 21,347 child-health conferences held by 37 States, with 136,813 infants and children of pre-school age examined, and 235 permanent child health centres established through the efforts of the States. Since 1920 child hygiene or child welfare divisions or bureaux have been organized in the departments of health in 13 States and the territory of Hawaii. At present all the States except one have such a bureau or division promoting child health, almost all of them being in the State department of health; in that one State the department of public health administers the work directly.

Sixteen States have been admitted to the United States birth-registration area since the passage of the Maternity and Infancy Act, so that at present 42 States together with the district of Columbia (all except Colorado, Nevada, New Mexico, South Carolina, South Dakota and Texas) have been admitted to what is known as the birth-registration area of the United States. This area included on Jan. 1, 1928, approximately 92% of the total population of the United States. In 1915 the infant mortality rate for the birth-registration area was 100; in 1920, 86; and in 1927 (provisional), 64. In 1920 only four States in the area had a rate below 70, and none had a rate below 60 deaths per 1,000 live births. In 1927, 29 States and the district of Columbia had a rate below 70, and of these, 11 were below 60. (Four of these 29 States had been admitted to the area since 1920.) Figures for foreign countries are not available for 1927, but in 1926, as a result of the lowering of the American rate to 73 only Australia, the Irish Free State, the Netherlands, New Zealand and the Union of South Africa—of the countries for which figures are available—had a lower infant mortality rate than the United States. In 1915 eight countries had lower rates.

On the face of the figures, maternal mortality from all causes appears to have been increasing in the United States. Analysis of the statistics shows that the certification of the causes of deaths has improved during the last 20 years. If allowance is made for the probable effect of this improvement in certification, the mortality from puerperal septicaemia has fallen throughout the period instead of increasing up to 1911 and falling since that time, as the figures taken at their face value would indicate, and the mortality from other puerperal causes has been approximately stationary. After allowances are made for the margin of error in the statistics of the United States and of other countries, it seems probable that the rate in the United States is actually considerably higher than in most countries. The maternal death rate per 10,000 live births in the birth-registration area of the United States was 68·0 in 1921, with only four States having a rate below 60. In 1926 it was 65·6, with 13 States having a rate below 60. Of these only two were admitted to the area since 1921. Analysis of the death rate shows a reduction in deaths from puerperal septicaemia which is probably due to the education as to the importance of prenatal care being carried on by the State health departments in co-operation with the children's bureaux.

Great emphasis is being placed on prenatal supervision by the State bureaux of maternal and infant hygiene, and there is evidence of great interest in the programme of work which is slowly getting under way. Studies of maternal mortality along lines laid down by the children's bureau consulting obstetrical committee are being made at the request of the State medical societies in some 11 States. Reports of activities undertaken under the Maternity and Infancy Act for the fiscal year 1926–27 show 3,231 prenatal conferences with 17,762 mothers in attendance, and 14 permanent prenatal centres established. More than 650 midwife classes were held in 16 States with an enrolment of almost 11,000 midwives, 6,000 of whom completed a somewhat formal course of instruction. Most of these were negro midwives who had had little or no previous training. Women in isolated rural districts are being reached by "prenatal letters" and itinerant conferences. More generally accessible hospital care during confinement is also receiving consideration.

In 1928, 21 States (Colorado, Florida, Idaho, Iowa, Kansas, Kentucky, Louisiana, Massachusetts, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Jersey, North Carolina, Pennsylvania, Rhode Island, South Carolina, Utah, Vermont and Virginia) and the district of Columbia had laws or regulations making medical inspection of school children mandatory, although in some of these States the examination required was only for certain defects or for communicable diseases. In nine States (Alabama, Connecticut, Georgia, Indiana, Maine, New York, Washington, West Virginia and Wyoming) it was mandatory for certain districts. Two States (Kansas and South Dakota) had laws specifically requiring only examination of the teeth of school children, and in 12 other States and the district of Columbia this was included in the requirement of a complete examination. Thirty-five States—all except Arkansas, Colorado, Kansas, Louisiana, Montana, Nebraska, New Hampshire, New Mexico, South Dakota, Oklahoma, Texas, Vermont, Wyoming and the district of Columbia—have laws with reference to physical education (usually including health teaching) in elementary schools, which are either mandatory or mandatory in effect. The teaching of health and health habits as distinguished from either medical inspection or physical education has greatly increased.

Bibliography.—S. Josephine Baker, *Child Hygiene* (1925); *Reports of the Administration of the Maternity and Infancy Act*, children's bureau, U.S. dept. of labour (1923–26); *Birth Statistics*, bureau of the census, U.S. dept. of commerce (annual); *A Health Survey of 86 cities*, by the research division of the American Child Health Association of New York city (1925). (G. Ab.)

MATHEMATICAL ARTICLES. The field of mathematics is so extensive and its divisions are so numerous that it is impossible to treat of the subject under any one head or even, as was formerly attempted, by means of a small number of topics like Arithmetic, Algebra, the Calculus, and Geometry. Readers who wish a general survey should also consult the articles on Mathematics, Nature of; Mathematics, Foundations of; Mathematics, History of.

In the field of number, elementary discussions are given under Arithmetic; Numerals; Finger Numerals and Fraction, while more advanced treatments will be found under Number; Number, Theory of; Number Sequences; Infinity; Continued Fractions; Complex Numbers; Quaternions; Magic Square and Mathematical Tables, and under such special heads as Bernoulli, Euler, and Stirling Numbers.

Algebra is considered in an elementary way under this topic, and in its more advanced aspects under Determinant, Diophantine Equations, Equations, Fermat's Last Theorem, Algebraic Forms, Series, Fourier Series, Groups, Interpolation, Linear Algebra, Polynomial, Probability and Error, and Trigonometry, and under a number of minor heads.

As in the other general branches, Geometry is treated in an elementary way under this general title, with more advanced topics separately considered. These include such special fields as Affine

GEOMETRY; ANALYSIS SITUS; ANALYTIC GEOMETRY; CIRCLE; CONIC SECTION; CONFORMAL REPRESENTATION; CURVE; CURVES, SPECIAL; DESCRIPTIVE GEOMETRY; DIAGRAM; DIFFERENTIAL GEOMETRY; GEOMETRIES, FINITE; LINE GEOMETRY; MANIFOLDS; MENSURATION; GEOMETRY: *Non-Euclidean;* PERSPECTIVE; POINT SETS; PROJECTIVE GEOMETRY; RIEMANNIAN GEOMETRY; SOLIDS, GEOMETRIC; SURFACE and TRIANGLE, with subjects like TRIGONOMETRY which are partly algebraic and partly geometric.

The "infinitesimal calculus" (differential and integral) is considered in a general way under CALCULUS, but various special branches are treated under DIFFERENTIAL EQUATIONS, DIFFERENTIAL FORMS, and MAXIMA AND MINIMA. Certain branches to which the word "calculus" attaches will be found under such special heads as BARYCENTRIC CALCULUS, CALCULUS OF DIFFERENCES, and CALCULUS OF VARIATIONS.

The general function theory is considered under the head of FUNCTION, with special articles on ELLIPTIC FUNCTIONS, BESSEL FUNCTIONS, and such functions as are appropriately treated under topics like TRIGONOMETRY.

The important field of instruments and models is represented by the articles on CALCULATING MACHINES, MATHEMATICAL INSTRUMENTS, and MATHEMATICAL MODELS. The graphic features are discussed under GRAPHIC METHODS IN MATHEMATICS, CHART, and NOMOGRAPHY.

In addition to the topics mentioned above, there are a large number on special subjects like KNOTS, BINOMIAL FORMULA, DUALITY and ORDINATE.

MATHEMATICAL INDUCTION, one of various methods of proof of a mathematical statement. It can best be understood from an illustration. Suppose that it is desired to prove that the sum of the first n odd numbers is n^2; that is, that

$$1+3+5+\ldots+(2n-1)=n^2.$$

It is evidently true when $n=2$, for $1+3=4=2^2$.

Suppose that it is true for $n=k$. In that case we should have

$$1+3+5+\ldots+(2k-1)=k^2.$$

Adding the next odd number, which is $(2k-1)+2$, or $2k+1$, we have

$$1+3+5+\ldots+(2k+1)=k^2+2k+1=(k+1)^2.$$

But this is just what we would have in the formula if we replace n by $k+1$. That is, if the formula is true for $n=k$, it is true for $n=k+1$.

The mathematical induction now consists in reasoning:

(1) We have shown that if the formula is true for any particular value of k, it is true when k is increased by 1.

(2) But we know by actual computation that it is true for the particular value 2.

(3) Hence it must be true for $2+1$, or 3; hence for $3+1$, or 4, and so on for all positive integers.

The method is used in numerous cases in series. For example, it is easily shown by this reasoning that, in the geometric series: $1+ar+ar^2+\ldots+ar^{n-1}$, $S=a(1-r^n)/(1-r)$; that the sum of the cubes of the first n numbers is $\frac{1}{4}n^2(n+1)^2$; and that the sum of the squares of these numbers is $\frac{1}{6}n(n+1)(2n+1)$.

MATHEMATICAL INSTRUMENTS. The term "mathematical instruments" in its widest significance includes various instruments used in drawing, surveying, astronomy, etc. We will here consider certain instruments designed to perform operations involving computation and measurement. Instruments and machines concerned with the mechanical performance of addition, subtraction, multiplication, division, etc., are described under CALCULATING MACHINES.

Instruments for Solving Equations.—Many instruments have been designed for the mechanical solution of algebraical equations. These are in general more remarkable for the ingenuity displayed in their design than for the practical value of the results obtainable. No instrument of this type has been brought into extensive use, but a few of them have found a limited application in cases where a considerable number of roughly approximate results are required. (*See* the works of Jacob, Horsburgh and Baxandall given in the bibliography.)

Planimeters.—The invention in 1814 of the first instrument for directly measuring an area bounded by an irregular curve is attributed to the Bavarian engineer, J. H. Hermann. The instrument was improved by Lämmle in 1816, and actually constructed in 1817. Tito Gonella of Florence in 1824 invented independently a similar instrument. It embodied a recording wheel which rolled on the surface of a cone, the angular motion of the wheel relative to that of the cone varying with the distance of the wheel from the apex of the cone. The position of the wheel on the cone was made to vary according to the length of the ordinate of the curve, thus the total angular rotation of the recording wheel gave the measure of area. Gonella soon afterwards replaced the cone by a disc.

The Swiss engineer Oppikofer invented in 1826 a planimeter which was similar to Gonella's first type (wheel and cone). This was first made successfully by Ernst, who improved it and made it for general sale. In 1849, Wetli of Zürich independently invented the disc type of planimeter adapted for both positive and negative co-ordinates, and the instrument was made by Starke of Vienna. The example shown in Pl. I. fig. 1, which was constructed about 1860, is engraved:—"Patent von Wetli & Starke, No. 103." It consists of a rotatable horizontal circular disc with a specially prepared fine upper surface on which the registering roller rests. The disc is mounted on a frame supported by three grooved wheels, which can roll on three parallel rails. Beneath the disc and mounted on the frame is a horizontal rod held between two pairs of guide rollers so that it can move in a direction at right angles to the rails. By means of a thin wire wound round the axle of the disc and attached to the ends of the rod the disc is given an angular movement proportional to the longitudinal displacement of the rod.

An upright frame screwed to the other end of the base-plate carries one end of the axle and the two divided circles which record the rotation of the registering wheel. Pivoted to this upright is a light frame carrying the registering wheel at its other end, which can be raised or lowered by means of a milled-headed screw; when the frame is lowered the wheel rests with a constant pressure on the disc. As the tracing point attached to one end of the rod is guided along the curve whose area is to be measured, the distance between the centre of the disc and the plane of the registering wheel is always proportional to the ordinate of the curve. The number of revolutions of the registering wheel gives therefore a measure of the area.

Hansen of Seeberg suggested improvements, which were embodied in the instrument made by Ausfeld, known as the Wetli-Hansen planimeter. John Sang of Kirkcaldy invented and made in 1851 a "planometer" of the wheel and cone type, which resembled that made by Ernst. An example of Sang's instrument is shown in Pl. I., fig. 2.

It will be seen that the revolving motion of the index-wheel is in proportion to the motion of the tracer up or down the paper, multiplied by the right and left distance of the wheel from the apex of the cone; and therefore, when the tracer is made to describe any complete perimeter, the whole rotatory motion of the index wheel represents the algebraic sum of the products of ordinates to every point in that perimeter, multiplied by the increment of their co-ordinates; thus it is a measure of the included space.

Clerk Maxwell in 1855 designed a planimeter in which pure rolling was substituted for the undesirable partial sliding of the register wheel on the cone or disc which occurred in previous types, but the instrument was never constructed. James Thomson in 1876 investigated the same problem, and in attempting to simplify Maxwell's mechanism, evolved his disc, sphere, and cylinder combination which could be applied to the construction of a planimeter.

This combination is shown in Pl. I., fig. 4, which represents the original model of Kelvin's harmonic analyser, made in 1876. The plane of the circular disc is inclined at 45°, and the sphere (shown displaced from its proper position) rests against the disc and the cylinder. The points of contact of the sphere are on a generating line of the cylinder and the horizontal diameter of the disc, and the distance of the sphere from the centre of the disc is controlled by the movement of a rod carrying two

forks, between which the sphere fits when the instrument is in use. The sphere acts as an intermediate variable gear, which communicates the rotation of the disc to the cylinder at a rate directly proportional to the distance between the axis of the disc and the centre of the sphere. This rod carries near its other end a pointer. When used as a planimeter, the curve whose area is required is wrapped round the larger cylinder, and as this is made to rotate the pointer is guided so as to follow the point of the curve which is on the topmost generating line. If the instrument is adjusted so that the sphere is at the centre of the disc when the pointer is on the axis of x, then the distance of the sphere from its central position will be always equal to the ordinate y of the curve, and the measuring cylinder will give, by the amount of its rotation, the value of $\int$ y·da—*i.e.*, the area of the curve. Owing to the difficulties and cost of construction, this type of planimeter was never made commercially, but Kelvin adopted the mechanism in his harmonic analyser.

A planimeter of the polar type, in which the recording wheel, kept in the required position by means of a guiding curve, rolled on the paper, was designed about 1856 by Gierer of Fürth. Bouniakovsky of St. Petersburg and Decher of Augsburg in 1856 each proposed an instrument of this type, in which the guiding curve was replaced by linkwork. C. V. Boys in 1883 invented a polar planimeter in which there was no slipping, but it was never constructed commercially.

Jacob Amsler, about 1854, invented his polar planimeter, which from its simple construction and low price very soon came into extensive use; up to 1884 Amsler had made over 12,000 examples of this instrument. An example made by Stanley about 1875 is shown in Pl. I , fig. 3. In using the instrument, the weighted point F is fixed and the tracing pointer T is guided exactly once round the outline of the figure whose area is to be measured. The difference of the readings on the graduated roller R before and after this operation gives the area of the figure in units depending on the radius TP of the tracing arm. Accurate setting of the tracing arm is facilitated by means of a fine screw adjustment. The example shown is of the "proportional" type—*i.e.*, the unit can be changed by altering the radius of the tracing arm.

About 1893, Coradi introduced his "compensation" polar planimeter, adopting a suggestion made by O. Lang, a Neuweid surveyor. In this modification of Amsler's polar planimeter the tracing frame and the pole arm are made in separate parts so as to allow the pole arm to be placed on either side of the tracer arm. Any error due to non-parallelism of the axis of the roller and the tracer arm can be eliminated by taking the mean of two readings, one obtained with the pole to the left of the tracer arm, and the other with the pole symmetrically to the right.

Integrator.—Amsler in 1856 invented his "integrator," which will measure larger areas than can be measured by the polar planimeter. It will also measure the moment and the moment of inertia of an area about any axis lying in the plane of the area. The instrument (Pl. I., fig. 5) is carried by a pair of wheels moving in a straight groove in a long steel bar, and a counterbalance weight is provided. If the tracing point T be guided so as to describe the outline of a plane figure, the graduated roller A attached to the swinging arm will register the area of the figure. The outer roller M will register the moment of the areas about the straight line described by the point where the axis of rotation of the instrument intersects the paper. The moment of inertia about the same straight line is deduced from the readings on the first roller and the inner one. Two gauges are provided for indicating the exact position of the straight line to which the moments are referred.

The integrator shown in Pl. I., fig. 6, was designed by Professor Hele-Shaw for determining areas, moments of stability and inertia by a single tracing of the figure. The principle of the instrument is similar to that of Amsler's integrator, but the instrument is designed specially to avoid slipping of the measuring wheel upon the moving surface, which in this case is a sphere.

In 1876 F. Hohmann invented a "precision" planimeter, which since 1880 has been made with various modifications by Amsler, Coradi, Gtt and others. In this type the recording wheel rests lightly on the specially prepared fine surface of a disc, so as to reduce friction due to slipping.

Important improvements due to Coradi are embodied in the instrument shown in Pl. I., fig. 7, which was made in 1915. The pivot end of the tracer arm is constrained to move in a circle whose centre is the same as that of the base plate, or pole disc. The edge of the pole disc is milled and engages with a small wheel on the axis of the revolving disc. This latter is made of aluminium and its upper surface is covered with smooth paper. As its axis, which is attached to the pole arm, revolves with the pole arm, the small wheel gears with the edge of the pole disc and the aluminium disc rotates through an angle proportional to the angle described by the pole arm. Upon this rotating disc rests the recording wheel, which is in turn rotated by its contact with the disc through an angle proportional to the area swept over by the tracer. The length of the tracer arm can be varied to suit the scale required, and the tracer point is provided with a support and a spring contact.

Ott (of Kempten, Bavaria) manufactures an "universal" planimeter which is made in three sections, and can be set up in different ways so as to form a compensation polar planimeter, a rolling planimeter, or a radial averaging instrument.

In 1887, Captain Prytz invented the simple knife-edge or "hatchet" planimeter, introduced and popularized in England by Professor Goodman. In its original form it consisted of a metal bar, bent at right angles at both ends, one of which (the tracer) was pointed, and the other in the form of a curved knife-edge. In using this instrument, a point is chosen at or near the centre of the area to be measured, and a radial line is drawn to the boundary. The point of the instrument is placed at the centre, and the hatchet pressed into the paper to form a dent. The point of the instrument is then made to follow the radial line and the boundary line, ultimately returning to the central point of the area, along the same radial line. The hatchet is again pressed into the paper to form a dent. If AB, AB^1 be the initial and final positions of the arm, the area described is equal to the length of the arm multiplied by the length of the arc BB^1. Within certain limits, the length of the chord BB^1—*i e.*, the linear distance between the initial and final marks made by the knife edge—may be taken instead of the length of the arc. In 1890 Prof. Goodman added a scale on the back of the instrument, which when applied to the distance between the two dents gave a direct reading of area in square inches.

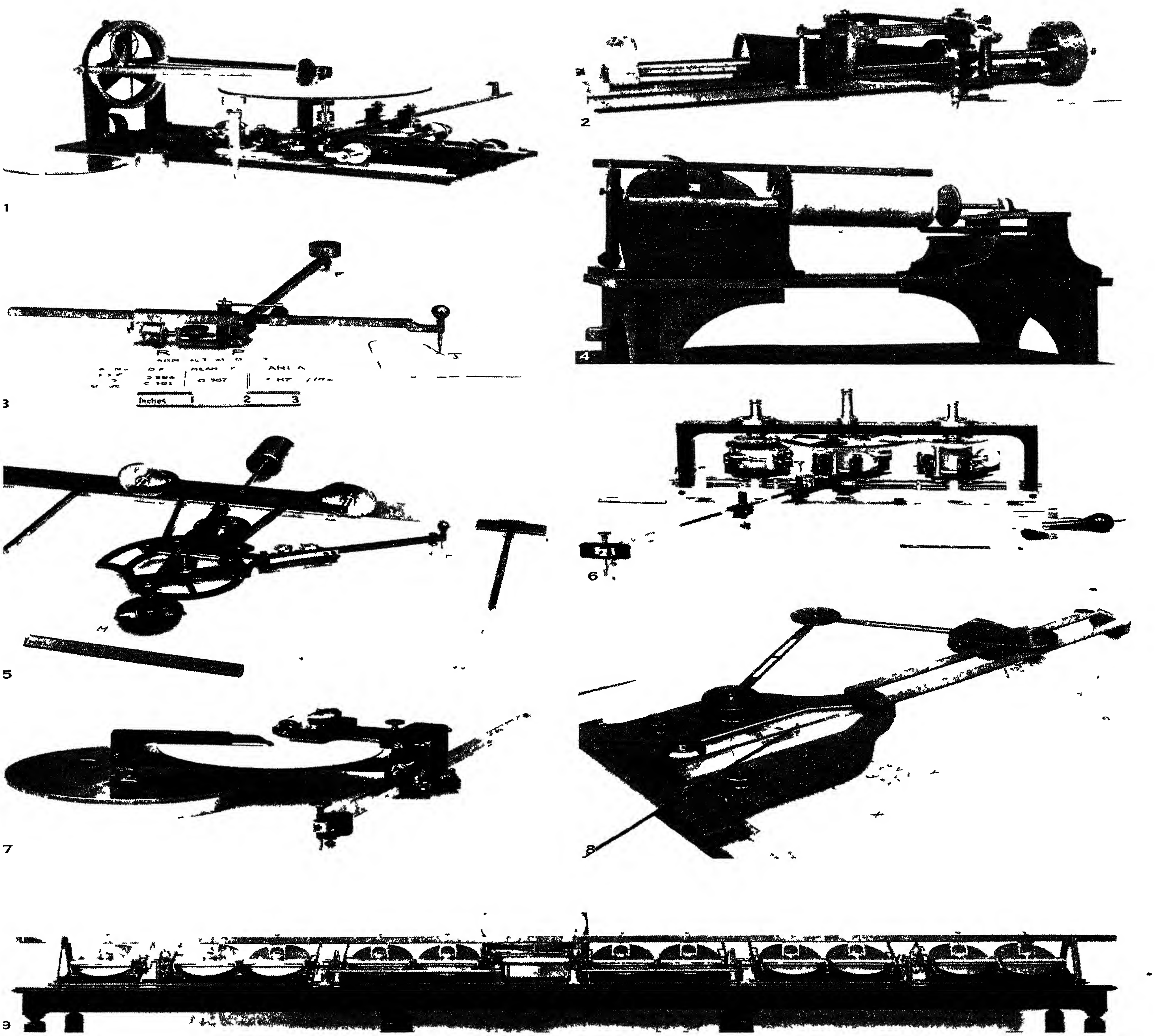
Integraphs.—This class of instrument is designed to draw the integral curve, corresponding to any given curve. The example shown in Pl. I., fig. 8 was invented by Professor C. V. Boys in 1881. It is an exact mechanical translation of the mathematical method of integrating $y{\cdot}dx$.

For any value of x the steepness of the curve drawn by the instrument is proportional to the ordinate of the given curve for the same value of x. The ascent then made by the new curve in passing from one ordinate to the other is a measure of the area between the given curve, the axis of x and the two ordinates.

The frame work is a kind of T-square (which can slide along a horizontal straight edge) carrying a fixed centre *B*, which moves along the axis of x of the given curve. A rod, passing always through *B*, carries a pointer *A*, which is constrained to move in the vertical line $e\ e$ of the T-square; *A* can then be made to follow any given curve. The distance from *B* to $e\ e$ is constant (k), therefore the inclination of the rod *AB* is such that its tangent is equal to the ordinate of the given curve$\div k$; so that *AB* has always the inclination of the required curve.

The curve is drawn by means of a three-wheeled cart of lead whose first wheel *C* is mounted like the steering wheel of a bicycle. By means of epicyclic gearing this wheel is kept parallel to *AB*, and can move only in the direction of its own plane. As *C* is always in $e\ e$ produced, the wheel draws the required curve if allowed to pass over a sheet of carbon paper.

The first integraph made commercially was invented independently by Abdank-Abakanowicz about the same time as that of Boys. This instrument has been made in considerable numbers, with modifications and improvements in design and construction,



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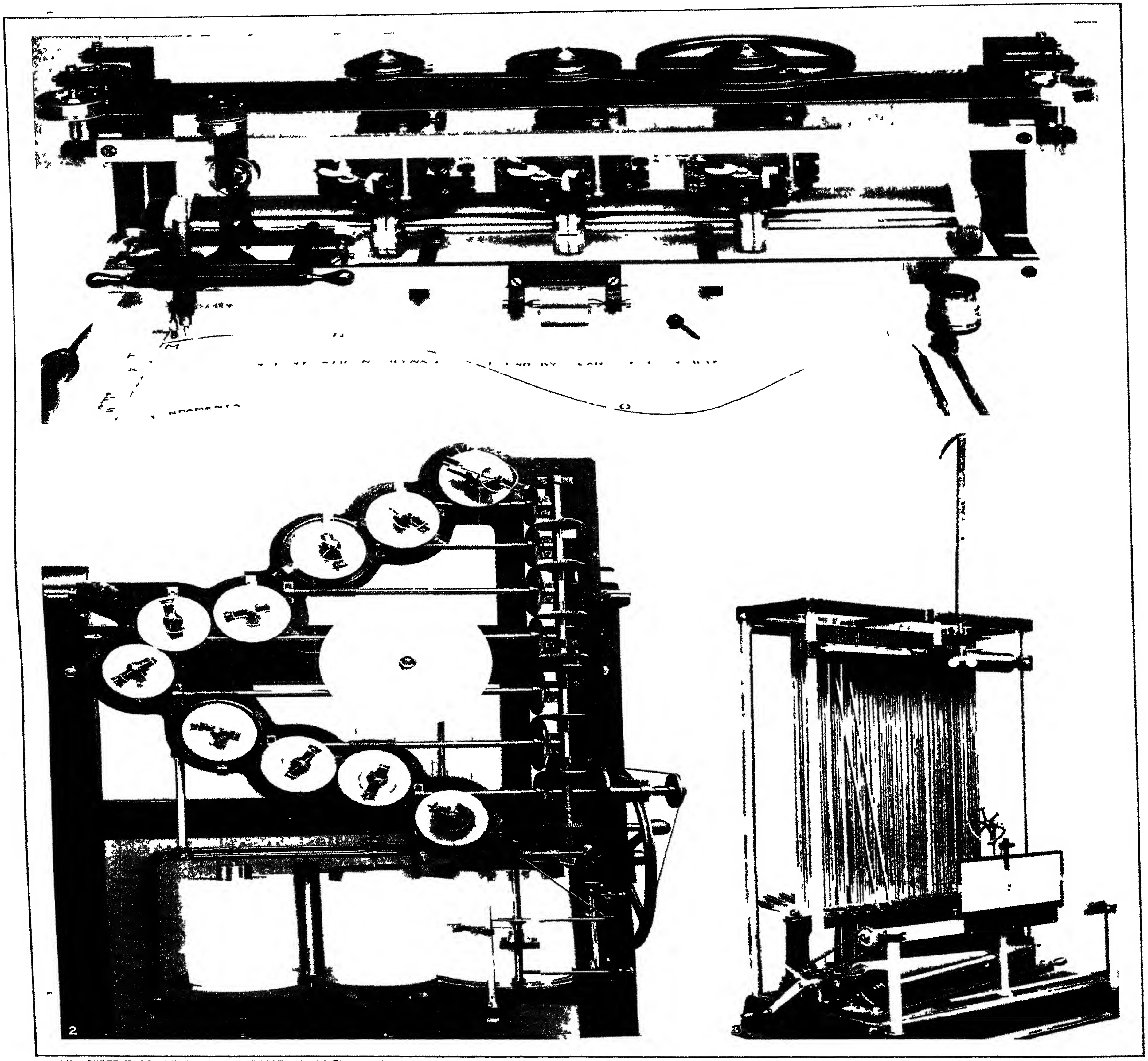
MATHEMATICAL INSTRUMENTS: PLANIMETERS, INTEGRATORS AND HARMONIC ANALYSERS

1. Wetli-Starke Planimeter. 2. Sang Planimeter. 3. Amsler Polar Planimeter. 4. Original Kelvin Harmonic Analyser. 5. Amsler Integrator. 6. Hele-Shaw Integrator. 7. Coradi precision-disc Planimeter. 8. Boys Integraph. 9. Kelvin Harmonic Analyser (All instruments described in text)



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HARMONIC ANALYSER, HARMONIC INTEGRATOR AND TIDE PREDICTING MACHINE

1. Henrici's Harmonic Analyser for obtaining mechanically the simple harmonic components of a periodic curve. Model made by Coradi in 1894
2. Kelvin's Tide Predicting Machine, 1876, for predicting, a year or years in advance, the depth of water for any port at every instant
3. Michelson and Stratton's Harmonic Integrator for obtaining mechanically the resultant of a large number of simple harmonic motions. 1904 Model

by Coradi of Zürich. Several polar integraphs have also been designed by Prof. Pascal. (*See* his *I Miei Integrafi,* Naples, 1914.)

An integraph has been developed recently by V. Bush, F. D. Gage and H. R. Stewart which plots continuously a curve representing the product of two functions introduced into the machine in the form of curves. It evaluates $F(x)$ against (x) from the expression $F(x)=\int_a^x f_1(x)f_2xdx,$ where f_1 and f_2 are known functions, formal or empirical. A full account of this machine is given by V. Bush and others in the *Journal of the Franklin Institute* (Jan. and Nov. 1927).

Harmonic Analysers.—In many scientific investigations the results of observations when plotted on paper take the form of an irregular curve which repeats itself at approximately regular intervals—*i.e.,* the curve, is periodic. Such a curve may be considered to be the sum of a series of simple harmonic curves, and it is the first object of harmonic analysis to find these simple component curves, which together build up a given periodic curve.

The various arithmetical or graphical methods which have been devised for this purpose are somewhat laborious, and Lord Kelvin in 1876 was the first to invent an instrument for performing the operation mechanically. This instrument was an adaptation of the disc-sphere-cylinder planimeter invented by his brother, James Thomson, in 1876.

The first completed instrument designed by Kelvin, and used for the harmonic analysis of tidal observations, is shown in Pl. I., fig. 9. It embodies 11 sets of the disc-sphere-cylinder combination, one for each harmonic. The curve to be analysed is wound on a central cylinder, and the simple harmonic angular motions of the proper periods are communicated to the disc by suitable gearing. The bar to which the tracer is attached has a series of pairs of projections which embrace the spheres. In actual use, the tracer is made to follow the curve, and the readings on the different integrating cylinders give the required coefficients.

Other harmonic analysers have been invented in 1894 by Henrici and Sharp, by Yule in 1895, Michelson and Stratton in 1898, Mader in 1909 and Boucherot in 1913. An example of Henrici's instrument, made by Coradi in 1894 is shown in Pl. II., fig. 1. A full description is given by Henrici in *Phil. Mag.* for July 1894; and in *Ency. Brit.,* 10th ed., art. "Mathematical Instruments."

A different type of harmonic analyser, in which the principle of action is based on Clifford's graphic method of harmonic analysis, was invented by O. Mader in 1909. An ordinary polar planimeter forms part of the instrument, and the tracer can be adjusted on its arm so as to suit any length of base from 20 mm. to 360 mm. Previous harmonic analysers could only be applied to curves of a fixed base; thus curves to any other base required redrawing to the given base before being analysed. In using the instrument, the guide ruler is placed parallel to the base line of the curve to be analysed, and the tracer of the planimeter is placed in one of the two holes of a toothed disc. These discs are easily interchanged.

For finding the coefficient A_n of the term $A_n \cos\left(n\,\frac{2\pi x}{a}\right)$ the toothed disc marked n is put in position and the tracer of the planimeter is put in the hole marked c. For the coefficient of the corresponding sine-term the tracer is put in the hole marked s. Toothed discs are provided for values of $n=1, 2, 3, \cdots 19$.

Harmonic Integrators.—When the component harmonic curves are known, or have been obtained by means of harmonic analysis the value of y for different values of θ in Fourier's formula can be found by computation. A great saving of labour is effected by performing this operation mechanically by means of "harmonic integrators," which are designed to draw a curve representing the value of y for all values of θ.

Tide-predicting Machine.—The method adopted by Kelvin is represented by the original model of his tide-predicting machine, made in 1872, and preserved in the Science Museum. In this model, eight pulleys are carried on axes at the ends of eight cranks of adjustable length, four on the upper side and four on the lower side of a rectangular wooden frame. A cord fixed at one end passes alternately under and over the lower and upper pulleys respectively, and at the other end carries a weight representing the marker. The centre of each pulley can thus describe a circle of adjustable radius, which circular motion is equivalent to the sum of two simple harmonic motions, one vertical and the other horizontal. The horizontal component of the circular motion leads to a slight motion of the cord out of its vertical position. If the radius of the circle described by the centre of each pulley is a small fraction of the distance between the upper and lower pulleys, Kelvin considered that the error introduced was practically negligible. The hanging weight will therefore perform a complex harmonic motion, which is the sum of the constituent vertical harmonic motions of the pulleys.

Pl. II., fig. 2 shows the first complete working machine made on the lines of the above model. There are ten wheels, one for each simple harmonic constituent obtained by means of the harmonic analyser, and the curve representing a year's tide for any port can be drawn in about four hours. The machine was constructed by A. Légé, under the superintendence of E. Roberts, who was also responsible for the design of later machines of larger capacity. In these machines the horizontal component was eliminated, the portions of the flexible wire between the upper and lower pulleys remaining always vertical. In the Liverpool machine made in 1924, there are 26 constituents; in the latest American machine (constructed 1896–1910) there are 37 constituents, and the tidal curves for 7 years can be run off in 12 hours.

A. E. Donkin in 1873 designed and constructed a harmonic integrator for compounding two simple harmonic motions. The curves are drawn by a pen on a paper secured round the surface of a cylinder. By means of two eccentrics simple harmonic motions are given to the pen and the cylinder respectively, the relative number of vibrations being variable by means of change wheels. Since both pen and cylinder move at once, the curve drawn shows the combination of the two motions.

The machine shown in Pl. II., fig. 3 was designed by Michelson and Stratton in 1898. The principle adopted is that of the addition of the elastic forces of spiral springs. In 1897 a machine of this type with 20 elements was made, and in the following year one with 80 elements, as in the example shown. An element consists of an eccentric (near the base of the machine) which, by means of an eccentric rod, communicates a simple harmonic motion to the end of a horizontal lever, curved to a radius equal to the length of a long rod, the foot of which may be clamped in any position along the lever. The top end of this rod actuates a lever whose end is attached to a small spring. Each of the 80 elements is similarly constructed, and the *amplitude* of the harmonic motion transmitted to the end of each spring is proportional to the distance of the foot of the corresponding long rod from the middle of the curved lever; for setting these distances accurately a special gauge is provided. The lower end of each of the small springs is attached to one end of a wide balance lever (made as a hollow cylinder on axial knife-edges), and the sum of their efforts is balanced by the action of a single powerful counter-spring. The motion of the lower end of the large spring is accordingly proportional to the algebraic sum of the motions of the upper ends of the small springs, and this resultant motion is magnified mechanically and conveyed to a pen, which registers the motion on a paper carried by a travelling plate driven by hand through the mechanism which rotates eccentrics.

By means of suitable toothed wheels forming a cone, the eccentrics are given periods increasing in regular succession; the eccentric nearest the hand wheel revolving 80 times while that at the opposite end revolves once. Turning the hand wheel produces at the upper ends of the small springs motions corresponding to $\cos\theta$, $\cos 2\theta$, $\cos 3\theta$, etc., up to $\cos 80\theta$, with amplitudes depending on the setting of the long rods.

The motions of the elements may be changed from those for *cosine* to those of *sine* by disengaging the cone and turning all the eccentrics through 90°, for which purpose a long pinion is provided. The machine is used as an *analyser* for finding the coefficients in a Fourier's series for a given periodic function.

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(D. B.)

MATHEMATICAL MODELS. The child's box of bricks is probably mankind's earliest acquaintance or contact with mathematical conceptions. The concrete forms of the cube which go to make up the puzzle pictures of the nursery, or the more complete selection of geometrical solids comprising cubes, prisms and cylinders which make up the "Building Sets" of the same period, must, however, in some measure, appeal to the latent mathematical faculty of the child mind, just as the abacus or "counting bead frame" may have stirred some little impulse in the arithmetical complex.

At an early stage in the child's career it is instructed that the cube, prism, etc., have many special properties which may, when used in right proportions, render them amongst the most pleasing forms of architecture. The simple doubled cube for example provides an exquisite form of pedestal and cross and the inherent beauties of the rectangular prism furnish a valuable architectural theme; also by means of models, it is possible to illustrate to the practical man a conception which may be perfectly clear to a gifted or trained mathematical mind.

A knowledge of plane geometry acquired without any reference to models may be said to flatten out the mind and to engender habits of thought which make it difficult at a later stage of mathematical education to explore space of three dimensions.

Plane Geometry.—Some early editions of Euclid had diagrams intended to be cut and folded, and a work by Cowley of 1752, *New and Methodical explanations of the Elements of Geometry*, included pieces of cardboard for the building up of various models. So talented a thinker and philosopher as Herbert Spencer appreciated the advantage of a model, for, writing to his father in January 1839, and speaking of his self-set task of regular, daily and systematic study of mathematics, he says "I have found out the grand principle of the projection of shadows and I feel almost certain of its correctness. To make myself still more satisfied I have made a model in pasteboard and I find that the real shadow is as exactly as possible what I had made it by projection."

Intuitive Geometry.—A valuable aid to the training of the young mathematical mind is to cut out, in cardboard, a number of equilateral triangles of the same size; the single triangle representing the plane figure; several piled one on top of the other with corresponding edges coplanar and corresponding corners collinear illustrate the solid figure of the triangular prism, while four of them placed together with pairs of edges coinciding, one of them being used as a base, gives the first of the regular solids, viz., the tetrahedron. The student may thus, by inductive process, quickly arrive at the historical selection of the five regular solids.

Simple models of this nature may be used to demonstrate common practical problems involving important principles relating to regularity and maximum and minimum values; as for example:—

1) Three straight lines of given total length enclose the greatest area when the lines form an equilateral triangle.

2) Four planes of a given total area enclose the greatest volume when the planes form a regular tetrahedron.

This statement could be varied by saying that for a given volume enclosed by four planes the surface is a minimum when the planes form a regular tetrahedron.

From these examples it will be remarked that regularity of shape is clearly connected with economy of bulk or volume, and where such regular forms occur in nature as in, say, crystal formations, we may naturally look for some explanation of maximum and minimum properties.

An important application of this style of model can be made by drawing out in the first place a regular hexagon of say, one inch edge. Set out upon each edge a further series of similar hexagons. Cut out with a sharp knife the first or inner hexagon and round the 18 lines of the outer edge of the figure, *i e.*, the boundary lines. Next cut along and through one only of the radial lines; then cut halfway through, and fold back or crease the remaining radials common to each hexagon. The paper may now be folded and provides a medium for the illustration of some interesting problems. First fold over one hexagon upon another when the "space" becomes pentagonal. Folding two we get the square; three, the triangle; the four fold giving a mathematical "solid of no depth." If a number of such developed surfaces be cut out of different colours and made up permanently by gumming the folds, practically the whole series of semi-regular polyhedra may be worked up in effective manner. Of particular interest in its physical application is the "two-fold," *i e.*, that giving a square and four hexagonal faces. Two of these units suitably connected at the joints by adhesive paper give the solid decatetrahedron of the Catalan Collection by Delagrave (1877); Pl. I. fig. 1 shows a polyhedron of 14 faces (6 square, 8 hexagon) which may be looked upon as a transition form between the cube and octahedron and which ten years or so later (1889) Lord Kelvin recognised as a shape providing minimum partitional area for cells of given volume, naming it the tetrakaidecahedron. (*See* SOLIDS: *Geometric.*) Pl. I. fig. 2 shows a somewhat similar construction of the "development" for the dodecahedron.

Mathematical models need not be accurate representations of a function in the same way, as, say, logarithmic tables or scales. They are not to be considered in the same category as graphs or nomograms. (*See* NOMOGRAPHY.) But they need to be constructed with reasonable care, and of suitable materials. It is sufficient if they enable the student to visualise the problem and follow the algebraic analysis involved. Mathematical models serve not to prove propositions but to demonstrate problems.

Materials for Models.—A mathematically plane surface has for example no counterpart in practice, but thin sheet metal or cardboard suffices for many purposes although in certain cases transparent celluloid or glass is to be preferred, whilst in others, strings, elastic, silk or cotton cords—which may be of different colours,—arranged closely together and parallel may be employed as where, for instance, it may be desired to demonstrate and variably warp or deform a surface; or to illustrate the continuously intersecting planes of descriptive geometry or the discriminant surfaces involved in algebraic equations of the 4th or 5th degree, etc.

Descriptive Geometry.—For the study of descriptive geometry (*q.v.*), perspective (*q.v.*), etc., a useful device is found in a pair of planes hinged together and possibly provided with a third plane of reference. Such folding planes if perforated allow of the setting up of problems in situ and the elucidation of the problems of orthogonal projection. The models introduced by Prof. Osborne Reynolds and G. Cussons of Manchester (1876) (Pl. 1 fig. 3) and the more recent developments by Mr. Andrew H. Miller of Glasgow University (Pl. I. fig. 4), are interesting examples of this class. In the former type the problems are permanently drawn out, in the latter they may be built up before the eyes of the student, precaution being taken in the design to avoid distracting the students' attention from the mathematics to the mechanism thus enabling the solution of the problems to be demonstrated in proper sequence step by step. In this class may be included the design (Pl. I., fig. 5), of Mr. H. G. Green of Nottingham University College and described in the *Mathematical Gazette* (London) No. 174, as *A Model for Figures in Three Dimensions,* which is partic-

ularly useful for three dimensional and trigonometrical studies. Posts may readily be fixed in the holes of the double base of the apparatus and cords as "Lines of vision," etc., serve to illustrate questions of the man and flagstaff type, subtended angles, etc.

Models of Wood.—Solid models of wood may be sectioned to elucidate many problems, an impressive example being shown in Plate I. fig. 6, a cube is cut into four different tetrahedra of equal volume, without making new corners. One face common to all four is that of half of the face of the cube; the sides being a face diagonal and two edges of the cube, the combination elucidating the problems relating to square root, etc.

A further example is the well known model of the *Binomial Cube, i.e.,* a cube built up of small cubes and prisms whose length of edge is represented by arbitrary value of a and b, and an entirely new and of course larger cube $(a+b)^3$ being formable by a combination of blocks equalling $a^3+3a^2b+3ab^2+b^3$.

The study of conic sections so frequently treated analytically, is much simplified by the use of a model, such as the right circular cone, in which plane sections are made

1) parallel to the base;
2) parallel to a generating line of the cone;
3) inclined to the axis at an angle greater than the semi-vertical angle of the cone;
4) inclined to the axis at an angle less than the semi-vertical angle of the cone,

giving respectively the *circle, parabola, ellipse,* and *hyperbola* (one branch), while a combination of solid, wire and plane model allows demonstration (as in fig. 1) of such solutions as the determination of the slope of a line by the method of inscribed spheres.

Problems concerned with the toroid (anchor ring) and cylinder, and interpenetration generally, can be most satisfactorily illustrated by wooden models since the common element is produced in the course of manufacture and its shape may be separately examined (Pl. I., fig. 7).

An interesting series of models is presented by the development of the higher species from the forms of the regular solids by cutting off corners and edges and/or producing the faces until they meet again. Kepler (1619) appears to have discussed the species and it is known that they received attention at the hands of Meister (1771) although definite records are lost; but they were rediscovered by Poinsot in 1809 and have since been widely treated in particular by Cauchy, Bertrand, Cayley and Wiener. Since in the tetrahedron the faces already cut one another, it will be evident that it cannot have any higher species. Producing the faces of the cube we get a group of three intersecting square prisms, the faces of which may intersect again at infinity.

The second species of the octahedron consists of two intersecting tetrahedra, whose surfaces when produced to the third species will be found to consist of six intersecting rhombic prisms having infinite volume.

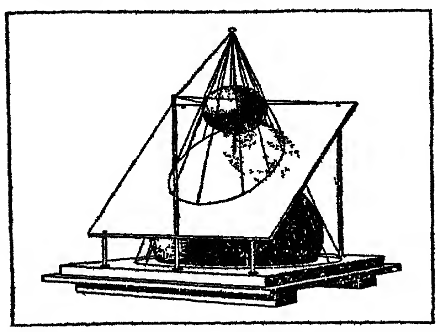


FIG. 1.—CONE WITH INSCRIBED SPHERES AND SECTION PLANE

Developing the solids in the systematic order thus defined, viz., the formation of succeeding solids by producing the faces of the first till they meet again, then producing the faces of the second to form the third, etc., etc., we arrive at four regular species for the dodecahedron and eight for the icosahedron. The four species of the dodecahedron are all regular-faced polygons, the first and third being ordinary pentagons, those of the second and fourth being pentagons of the second series or pentacles. Of the eight species of icosahedron, derived in systematic order, only the first and seventh are regular, their faces being equilateral triangles. (*See* SOLIDS: *Geometric.*)

In making up such models it is generally convenient to start with a model of the first species and build up or convert it into the second species by adding to each face the appropriate complement by dowelling it to the intersecting corner, the forms of the faces of the various complements being obtained from the complete plan of the face of the polyhedron.

Technical Construction.—*Symmetrical Solids* and surfaces of revolution can be turned in a lathe, a templet representing a plane section containing the axis being applied to the work from time to time until the whole solid of revolution is worked up.

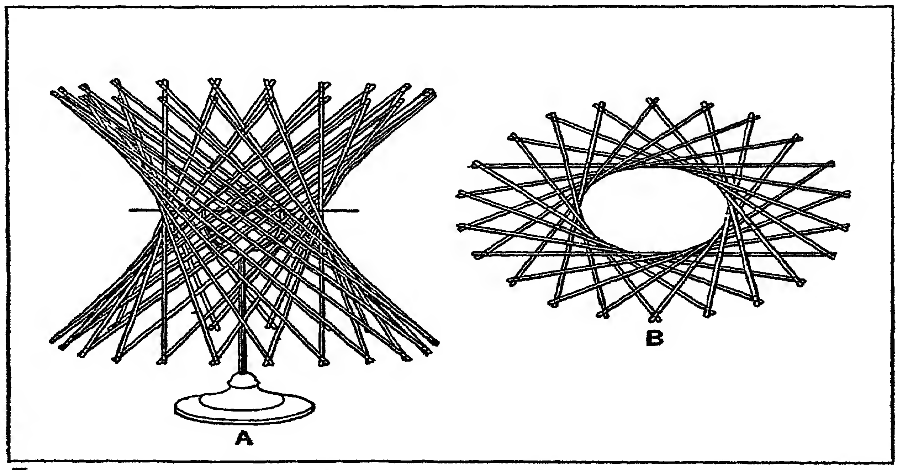


FIG. 2A.—MOVABLE ROD MODEL OF ONE SHEET: HYPERBOLOID SHOWING BOUNDARY ELLIPSE HYPERBOLE
FIG. 2B.—MODEL OF TYPE SIMILAR TO PLATE I. FIG. 12, BUT ARRANGED TO SHOW IT REVERSED

Surfaces which are non-symmetrical round the axis may also be turned or formed in a suitable lathe having a chuck capable of eccentric motion. Such models may attain a high order of accuracy since micrometer measurements may be applied to the work in the machine. It is of course easy to represent many of the surfaces by means of fixed wires shaped and assembled to represent their principal axes (Pl. I. figs. 8, 9, 10), but a more intriguing series of flexible models can be made up of rods or strips, pin jointed or hinged at their extremities since such provide a mechanism whereby ruled surfaces of the hyperboloids, etc., may be demonstrated and allow of conversion or "reversal" into their confocal surfaces. (*See* figs. 2a and 2b.)

Thread Models.—Ruled surfaces, *i.e.,* surfaces generated by the motion of a straight line, fall naturally into a class for easy modelling, since the generating line can be represented by successive stretched threads. (*See* SURFACE.) Thread models can, therefore, illustrate a wide variety of combinations as in Plate I. fig. 12, which consists of two circular discs drilled with equidistant holes closely together, supported as shown and threaded with weighted cords so that the cords may slide through the lower holes.

We have in this model a demonstration of

1) a cylinder—when the discs and cords hang freely,
2) a hyperboloid of revolution—when one or other disc is rotated slightly relatively to the other,
3) the limiting position of a pair of cones upon further rotation,

thus providing an interesting example of maximum and minimum values since the cylinder represents the maximum volume for a given perimeter and the cone the minimum, the circular ends being of constant value. Threads stretched as generators across the bars of a jointed quadrilateral of which the sides are movable in pairs may be used to illustrate the changes from a plane through all forms of paraboloid to double plane. Pl. I. fig. 11 shows an example; the hyperbolic paraboloid generated by a single system of right lines. It comprises two bars pierced with equidistant holes, one bar being fixed, the other capable of swinging round an axis which can also be inclined at different angles to the fixed bar.

With the bars placed parallel, the strings indicate a plane. When inclined to one another yet in the same plane they still illustrate a plane but when the bars are not in the same plane the strings assume the surface of a twisted plane; viz., the hyperbolic paraboloid, a natural surface for the maximum cleavage properties of

a ploughshare. It may be observed from the model that no two strings lie in the same plane and therefore no part of the surface is truly plane. Such a surface cannot be made by simply twisting a plane sheet of metal which would show malformation on opposite sides of the axis.

Space Curves.—There remain, however, still further types of example wherein space curves of the 3rd order are represented by the developable surfaces of their tangents.

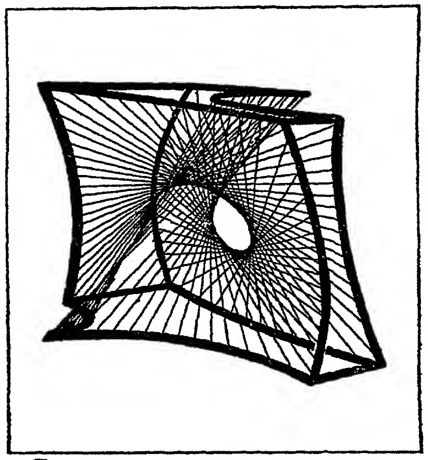


FIG. 3 —CUBIC SPACE CURVES
Tangent surface of cubic ellipse

Such a series would comprise models showing:—

1) the curves with their asymptotes,

2) the developable tangent surface,

3) the curves as partial sections of cones and cylinders,

4) the two dual generations of the curves, their developable surface, etc.

An example shown in Pl. I fig. 13, illustrates the involute of the planes which touch two conic sections possessing a common tangent.

These models would demonstrate the cases of singularity which can arise in a position of a space curve according as the point or flexion plane is a progressive or regressive element and also the relation of the position to infinite distance.

Examples of the problems connected with the theory of *cubic space curves—cubic ellipses, hyperbolas, parabolas,* etc.,—are shown in fig. 3, viz, the tangent surface of the cubic ellipse, the surface which separates the points of the first case from those of the third, and in fig. 4 the horopter,—a symmetrical cubic ellipse lying on a circular cylinder both of them of special application in physiological optics.

A physical-science application is given in fig. 5 which illustrates the form of equipotential lines and lines of force corresponding to two electric conductors charged to the same sign.

Helical Surfaces.—Helical surfaces may best be demonstrated by either shaped wires or small surfaces of tinplate hinged together, the former providing the cheaper but a less flexible medium. Typical examples are the helical surfaces of Pl. I. fig. 14, where generators and principal tangent curves are picked out in different colours to render them distinguishable, and in Pl. I. fig 15, that of a model composed of small hinged sections, we have an illustration of the same problem solved by the application of the idea of polyhedra to the theory of the bending of surfaces.

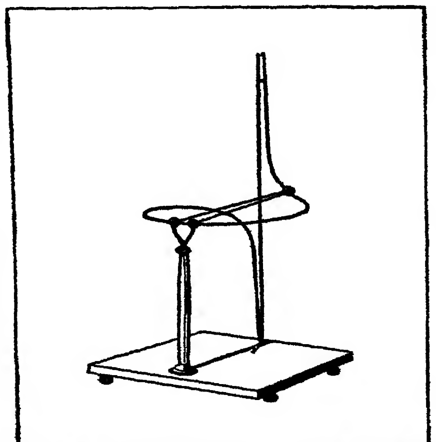


FIG. 4.—THE HOROPTER, A SYMMETRICAL CUBIC ELLIPSE LYING ON A CIRCULAR CYLINDER

The same model also exemplifies the Voss surface demonstrated by finite plane elements of surface hinged together to enable them to be bent in two conjugate systems of geodetic lines.

Cardboard Models.—In Pl. II. fig. 1 is illustrated an example of model made up of thin sheets, *e.g.,* cardboard circles of regularly varying diameters set equally apart in parallel vertical planes, whereby it is possible to evolve the whole series of surfaces of the second order (ellipsoid, hyperboloid, paraboloid, etc.).

A further advantage of this type of model is that the sections may be interlocked across an axis and thereby deformed at will, a feature which may be reached in another way as in the deformable circles of figs. 2 and 3 of Pl. II. In this type a number of different sized wire circles are loosely jointed together across a diameter by a special form of hinge—Wiener's limited joint—which allows at once an extraordinary freedom and restraint

The figure shows the limiting positions of circle and sphere and the formation of prolate and oblate ellipsoids Similar models may be readily made to illustrate the elliptic paraboloid, and paraboloids of one sheet or of two sheets, and of double cones, etc., the method of construction with its property of semi-transparency enabling a clear idea to be obtained of the constant relationship of the asymptotic cone and that the lengths of all segments of generating lines remain unaltered.

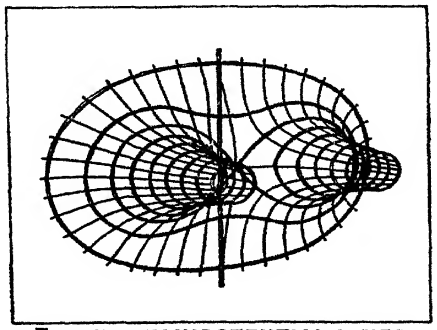


FIG 5 —EQUIPOTENTIAL LINES

Surface Models.—The method of representing the surfaces of the 2nd order by thin sheet circles arranged in parallel planes suggests the means of producing what is probably the most generally useful of all types, viz, surface models of wood, clay or plaster. A model of a cubic surface for example may be considered as built up of a number of parallel horizontal sections each of which is a plane cubic curve

In order to produce such models it is in the first place essential to prepare templets, which embody the particular function to be illustrated. If then a series of such be erected in the appropriate coordinate planes, a surface will ultimately emerge which may be definitely outlined by narrow strips of thin muslin or fabric fixed into position by a plastic medium such as claywash, wax or plasticene, from which subsequently a plaster cast may be taken On the permanent surface may be marked appropriate axial and geodetic lines and to it tangent planes of say transparent celluloid, etc., may readily be applied. Surface models may alternatively be made up of thin layers of wood suitably shaped, the smooth contour being filled in by wax, or they may be evolved by applying templets after the manner employed in shaping a model ship's hull. Such a model may of course represent a function of pure mathematics, *e.g.,* $f(x, y, z)=0$ or some physical function say of the pressure volume and temperature of a gas, as in the case of Prof. James Thomson's model of 1871, made to illustrate the data obtained by Prof. Andrews in his classic experiments on the relation between temperature, pressure and volume of a constant mass of carbonic anhydride when the values were plotted, with temperature as the x, pressure as the y, and volume as the z coordinates respectively.

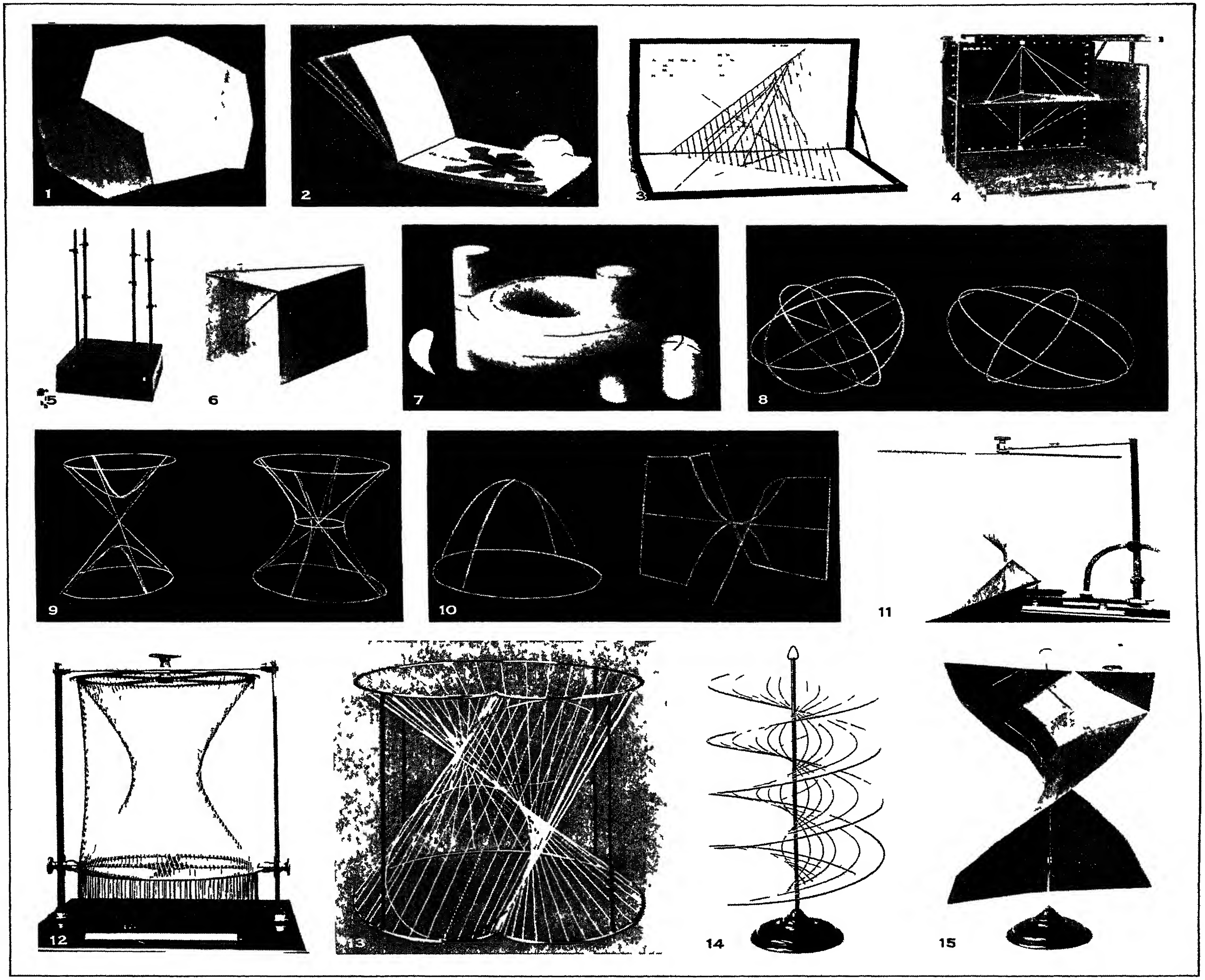
A somewhat later application of the method was made by Maxwell who as the outcome of a suggestion by Prof. Willard Gibbs used the quantities *volume, energy* and *entropy* in making his famous *thermodynamic surface model* in which the properties of a substance in its solid, liquid and gaseous or any conditions in which these states co-existed are indicated by the geometrical properties of the surface.

Maxwell showed how isothermal and isopiestic lines could be drawn upon it and that there is one position of the tangent plane in which it touches the surface in three points which represent the solid, liquid and gaseous states of the substance when the temperature and pressure are such that the three states can exist together.

Plaster Models.—Plaster casts can obviously be produced at less cost than the original mould, so that wherever feasible the method affords a convenient means of reproducing surface models of either constantly varying functions as in surfaces of revolution or of irregular or non-continuous form.

The former case is typically represented by Pl. II. fig. 4, the surface of rotation of the tractrix about its asymptote, upon which may easily be scribed after moulding the body, the geodetic lines and principal tangent curves, or such surfaces of constant mean curvature shown in Pl. II. fig. 5 which illustrates (left to right) (1) *onduloid,* (2) *nodoid,* (3) *ring of the nodoid* arising by rotation of the loop, and (4) the *catenoid,* a minimum surface whose constant mean curvature is null.

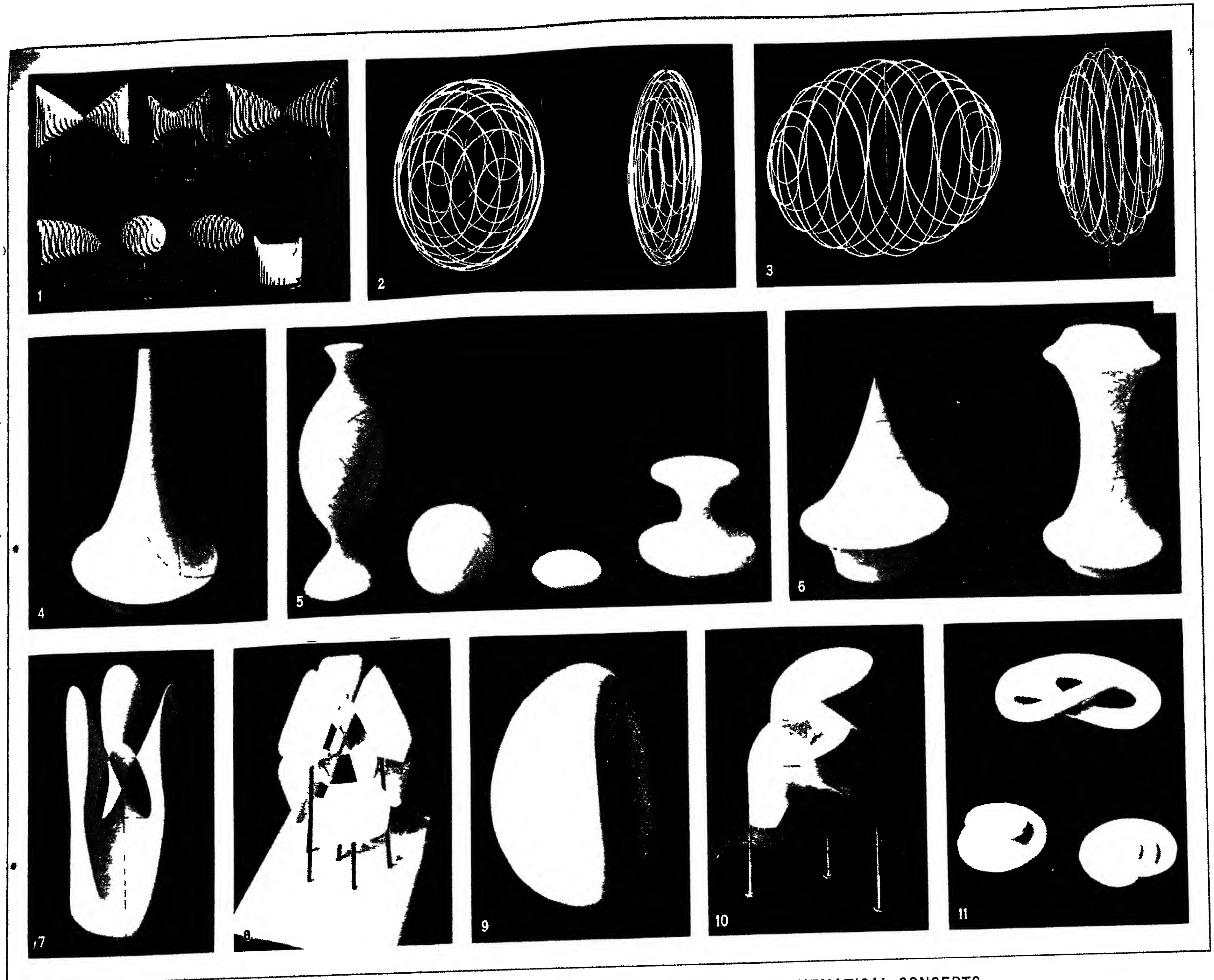
MATHEMATICAL MODELS



MODELS ILLUSTRATING PLANES, SOLIDS AND OTHER MATHEMATICAL FIGURES

1. Paper model of polyhedron having 14 faces (6 square, 8 hexagon)
2. Dodecahedron; with page showing shape in one plane of all surfaces of the model
3. Folding planes for use in the study of descriptive geometry
4. Model for geometrical study. Planes and solids may be built up in the classroom by changing adjustment of shelf and threads
5. A model for figures of three dimensions. A recent development, useful in three-dimensional and trigonometrical studies
6. Wood model: a cube of four different tetrahedra of equal volume
7. The torus (anchor ring) and cylinder, showing interpenetration
8. Wire models for the demonstration of ellipsoid figures
9. Wire models showing two sheet and one sheet hyperboloid
10. Wire figures of the elliptic and hyperbolic paraboloids
11. Bar and thread model; to illustrate changes from the plane through all forms of paraboloid to double plane, the threads acting as generators
12. Disc and thread model for demonstrating (a) cylinder, (b) hyperboloid of revolution; (c) limiting position of a pair of cones
13. Space curve model illustrating the involute of the planes which touch two conic sections possessing a common tangent. Curves and supports are of wire; threads serve to indicate sides of cones
14. Shaped wires on an upright support demonstrating helical surfaces; generators and principal tangent curves are of different colours
15. Helical surfaces: model made of small hinged sections with a vertical support; polyhedra applied to theory of the bending of surfaces

MATHEMATICAL MODELS



CARDBOARD, WIRE, PLASTER AND WOOD MODELS OF ADVANCED MATHEMATICAL CONCEPTS

1. Models illustrating the whole series of surfaces of the second order
2 and 3. Wire circles loosely jointed by special hinge (Wiener's joint) allowing an extraordinary degree of either freedom or restraint
4. Plaster model: surface of rotation of tractrix about asymptote
5. Plaster models: (left to right) onduloid; nodoid; ring of nodoid arising by rotation of the loop; catenoid, a minimal surface
6. Surface of constant negative curvature (1) cone type (2) hyperboloid type
7 Third order surface; four real conical nodes and tangent curves
8 Kummer surface: singularity surface of a complex of second degree
9 Roman surface (Steiner); three intersecting double straight lines
10 Model illustrating minimal surface; contains system of parabolas
11. Riemann surfaces

Surfaces of rotation having a constant negative measure of curvature as in Pl. II. fig. 6, that on the left being of the cone type and bearing geodetic and asymptotic lines, that on the right illustrating the hyperboloid type and being marked with parallel geodetic lines and geodetic circles.

Pl. II. fig. 7 illustrates a surface of the third order showing four real conical node points and the principal tangent curves.

A form of Kummer surface (singularity surface of a complex of the second degree) is shown in Pl II. fig. 8. It is of the fourth order of the fourth class and has sixteen real node points and the same number of double tangential planes.

A further example of a surface of the fourth order, four planes making contact along circles, is the so-called *Roman surface* due to Steiner and shown in Pl. II. fig 9. It has three intersecting double straight lines and is of the third class. The asymptote lines are indicated.

An interesting example of a model illustrating a minimum surface is shown in Pl. II. fig. 10. It contains a system of real parabolas the planes of which make a constant angle with a fixed plane of the space.

Fundamental examples in connection with the function theory are shown in Pl II. fig. 11, where is shown: (1) (at top) Simply connected Riemann surface (two leaf) which contains in its interior one point of double inflexion of the first order. (2) (bottom left) A simply connected Riemann surface (three leaf) with an interior point of double inflexion of the second order. (3) (bottom right) A triply connected Riemann surface with a boundary line turning back upon itself. Fig. 6 illustrates the function $W^4=l-Z^4$, and the course of the elliptic functions $p(n)$ and $p^l(n)$ in the Weierstrassian series is shown in fig. 7.

Linkages and Kinematical Models.—Linkages may be defined mathematically as systems of bars connected by pin joints or hinges, to allow deformability without sliding motion. All algebraic curves may be generated by such articulated linkages, Kempe, Darboux, etc, having analysed the position very fully, and numerous attempts have been made to solve by linkage systems the mathematically indeterminate trisection of an angle. These devices fall, however, into the classification of instruments rather than models, and space shortage forbids their treatment here, a qualification which applies also to a treatment of kinematical models dealing with related motion.

Stereoscopic and Optical Methods.—Another series of models has been developed to a limited extent by producing a solid effect from plane figures by means either of viewing bi-coloured

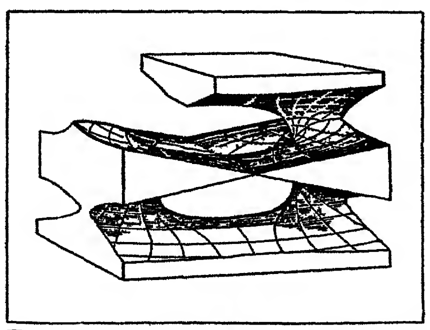


FIG. 6.—ILLUSTRATING THE FUNCTION $W^4=L-Z^4$

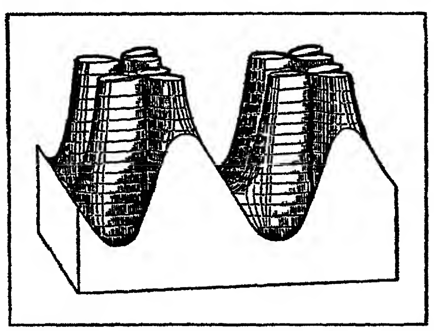


FIG. 7.—WEIERSTRASSIAN SURFACE

diagrams through absorption screens or the more common method of displaced image.

Examples of the first method are the *plastographs* or *anaglyps* by Mr. H. Richard of Chartres, and in England by Mr. G. F. Smith, who have produced examples illustrating the interpenetration of prisms, sections of a helicoid, etc.

The second method is represented by the series designed by Sir George Greenhill to illustrate gyroscopic movements, *e.g.*, the locus of the axis of a spinning top or Maxwell gyroscope.

Quite recently a series of lantern slides illustrating certain algebraic curves, viz., the dual singularities, etc., involved in the theory of cubics and the construction of hyperelliptic and quartic curves has been developed by Prof. Arnold Emch at the University of Illinois, who has also produced a cinematograph film of the Poncelet polygon, *i.e.*, showing the succeeding positions or continuous movement of a triangle remaining inscribed and circumscribed to two fixed circles respectively.

A novel method of treatment is that devised by Prof. Papperitz of Freiberg, viz., kinodiaphragmatic projection. The device consists essentially of a variable speed gear box capable of imparting rotatory motion to a transparent diaphragm placed parallel to and immediately in front of the condenser of an optical lantern. Upon the diaphragm may be fixed any combination of thin polished wires which will reflect narrow beams of light into the focussing lens. Beyond and in front of the lens is placed a second rotating axis which may be vertical or inclined, and carry a surface model—say, a sphere, cylinder, etc.,—built up of wires, spaced apart.

Shadowgraphs are thus projected on to a distant screen, the forms being continuously changed or dissolved into one another according to their relative axial speeds, and by the rotation of stereomatical bodies and simultaneous projection it is possible to produce three-dimensional images in space. (G. W. Cu.)

MATHEMATICAL SOCIETIES AND PERIODICALS. The number of mathematical societies, clubs, and circles organized since the early one at Hamburg in 1690 is exceedingly large, but the number of mathematical periodicals since the seventeenth century is very much larger. Important mathematical work of a country is often given in publications of its academies or societies. Hence any listing of mathematical periodicals must take account of these. Space limitations require that a selection only be made from the vast amount of available material regarding societies and periodicals. That each country's contribution in this regard might be clearly set forth, the material has been arranged alphabetically according to countries.

The great national mathematical societies were established in their countries in the following order: Russia, Great Britain, France, Italy, United States and Germany.

ARGENTINA.—The Sociedad Matemática Argentina was organized at Buenos Aires in 1921 and in 1924 adopted *Revista de Matemáticas y Fisicas Elementales* (1919–24), as its official organ, the name being then changed to *Revista Matemática* (1924+). These periodicals were continuations of *Revista de Matemáticas,* Buenos Aires (1916–18). Material of more importance has appeared in *Universidad Nacional de la Plata, Facultad de Ciencias Físicas, Matemáticas y Astronomicas* (1901+), and *Boletín del Seminario Matemático Argentino* (1928+).

AUSTRALASIA.—There are some mathematical papers in *Royal Society of New South Wales, Journal and Proceedings* (1867+), Sydney; and *Royal Society of Victoria, Proceedings* (1854+), Melbourne.

AUSTRIA.—*Monatshefte für Mathematik und Physik* (1890+) has been issued by the Mathematical Seminary of the University of Vienna. The *Anzeiger* and *Denkschriften* and *Sitzungsberichte, mathematisch-physikalische Klasse* (1848+), of the K. Akademie der Wissenschaften, are of importance for the mathematician.

BELGIUM.—The Société Mathématique de Belgique, founded at Brussels in 1921, adopted *Mathesis, recueil mathématique à l'usage des Écoles Spéciales,* Ghent (1881+, suspended 1916–20) as its official organ. But the chief sources for research material in mathematics are: *Académie Royale des Sciences, des Lettres et des Beaux-Arts,* Brussels, *Bulletin* (1832+), and *Mémoires* (1840+); and *Société Scientifique de Bruxelles, Annales* (1875+; suspended 1914–19), Louvain. Another publication of this Société, *Revue des Questions Scientifiques* (1877+), contains interesting material, especially for the history of mathematics. *Correspondance Mathématique et Physique* (Quetelet) published at Ghent and Brussels (1825–39) was of more importance than *Nouvelle Correspondance Mathématique,* Brussels (1875–80). A recent Flemish publication at Ghent is *Wis-en Natuurkundig Tijdschrift* (1921+). *Isis* (1913), a journal devoted to the history of science was founded, and is still conducted, by Sarton. After one and a half volumes had been issued the publication was continued in the United States (*see*

there).

CZECHOSLOVAKIA.—The Spolku pro Volné Přednášky z Mathematiky a Fysiky (society for free lectures on mathematics and physics) was founded in 1862 and flourished till the organization in 1869 of Jednota Českých Mathematiků, called Jednota Československých Mathematiků a Fysiků since 1921, with over 2,000 members. It is the most affluent mathematical society in the world, owning its own press and building where it does an extensive business in the publication of texts used in elementary schools throughout the country. Among its mathematical publications are: *Časopis pro Pěstování Mathematiky a Fysiky* (1872+), *Archiv Mathematiky a Fysiky* (1875–79), *Rozhledy Matematicko-Přírodovědecké* (1893–1921; as a separate publication 1922+), and a score of treatises on topics in the fields of mathematics and physics. *See* V. Posejpal, *Dějepis Jednoty Ceských Mathematiků*, Prague, 1912.

Publications de la Faculté des Sciences de l'Université Masaryk (1921+) Brünn, contain a number of mathematical monographs.

DENMARK.—The important mathematical work is published in *K. Danske Videnskabernes Selskab*, Copenhagen, *Mathematisk-Fysiske Meddelelser* (1917+); *Oversigt* (1814+); and *Selskabs Skrifter, Naturvidenskabelig og Mathematisk Afdeling* (1824+). For more elementary mathematics were *Tidsskrift for Mathematik* (1859–89) Copenhagen, and *Maanedsskrift for den Elementaere Mathematik* (1886–89), continued as *NytTidsskrift for Mathematik, A* [elementary], *B* [advanced] (1890–1919), which were continued by the Matematik Forening i København, founded in 1905, as *Matematisk Tidsskrift, A, B* (1919+). For at least a dozen years previously this society had published a *Medlemsblad*.

DOMINION OF CANADA.—Some mathematical papers are to be found in *Proceedings and Transactions of the Royal Society of Canada* (1882+).

FINLAND.—Mathematical papers of importance are to be found in: *Finska Vetenskaps-Societeten, Acta, Societatia Scientiarum Fennicae* (1842+) and *Commentationes Physico-Mathematicae* (1922+); and in *Suomen Tiedeakatemia, Toimituksia, A* (Finnish Academy of Sciences, Annales, A, 1909+). The papers of the latter are entirely in English, French and German.

FRANCE.—The Société Mathématique de France, founded at Paris in 1872, has about 415 members and publishes a *Bulletin* (1873+). The other most important periodicals for mathematics are: *Annales Scientifiques de l'École Normale Supérieure* (1864+); *Journal de l'École Polytechnique* (1795+); *Journal de Mathématiques Pures et Appliquées* (1836+), continuation of *Annales de Mathématiques Pures et Appliquées* (1810–32); *Annales de la Faculté des Sciences de l'Université de Toulouse pour les Sciences Mathématiques et les Sciences Physiques* (1887+); *L'Institut de France, L'Académie des Sciences, Comptes Rendus* (1835+); *Société Philomathique de Paris, Bulletin* (1789+); and *Association Française pour l'Avancement des Sciences, Compte Rendu* (1872+). There is much of mathematical interest in *Revue du Mois* (1906–20) (Borel) and *Revue de Métaphysique et de Morale* (1893+), Paris.

Other periodicals are: *Nouvelles Annales de Mathématiques* (1842–1927); *L'Intermédiaire des Mathématiciens* (1894–1925) of value for bibliography and history; *Revue de Mathématiques Spéciales* (1890+) for secondary schools; and *Journal de Mathématiques Élémentaires et Spéciales* (1877–1901) (de Longchamps).

GERMANY.—The oldest mathematical society in existence is the Mathematische Gesellschaft in Hamburg, founded in 1690 as "Kunstrechnungsliebende Societät," and continued, 1790–1876, as "Gesellschaft zur Verbreitung der mathematischen Wissenschaften." It has about 100 members and has published *Mitteilungen* (1873–1880, mimeographed; 1881+, printed) and at least 80 issues of *Jahresbriefe* or *Jahres-Berichte* or *Berichte* (1723–1878). What constitutes a complete set is unknown. The national society, Deutsche Mathematiker Vereinigung, was founded in 1891 and has about 1,100 members. It has published *Jahresbericht* (1892+), with *Ergänzungsbände* (1906–14). The Berliner Mathematische Gesellschaft, founded in 1901, has about 300 members, and has published a *Sitzungsberichte* (1902+). The Gesellschaft für angewandte Mathematik und Mechanik, which was founded at Leipzig in 1922, has approximately 320 members.

Four of the most important periodicals in the world are: *Mathematische Annalen* (1869+), *Mathematische Zeitschrift* (1918+), and *Journal für die reine und angewandte Mathematik* (Crelle, 1826+), and *Jahrbuch über die Fortschritte der Mathematik* (1871+) an annual survey of mathematical literature since 1868. Other publications of special value for the mathematician are: *Nachrichten, mathematisch-physikalische Klasse*, of the Gesellschaft der Wissenschaften (1845+), Göttingen; *Preussische Akademie der Wissenschaften*, various publications (1710+); *Bayerische Akademie der Wissenschaften, Sitzungsberichte* (1860+) and *Abhandlungen* (1829+); *Sächsische Gesellschaft (Akademie) der Wissenschaften, Berichte* (1846+) and *Abhandlungen* (1849+); Heidelberg, *Akademie der Wissenschaften, Sitzungsberichte* (1910+). Among others are: *Archiv der Mathematik und Physik* (1841–1920); *Zeitschrift fur Mathematik und Physik* (1856–1917) to which *Abhandlungen zur Geschichte der mathematischen Wissenschaften* (1877–1913) was a supplement (1877–1900); *Mathematisch-naturwissenschaftliche Mitteilungen*, Tübingen and Stuttgart (1884–1922; no numbers 1893–98; title extended, 1899+, by: *im Auftrag des mathematisch-naturwissenschaftlichen Vereins in Württemberg*), which in 1891–92 had the title *Mitteilungen des mathematisch-naturwissenschaftlichen Vereins in Württemberg;* University of Hamburg, *Abhandlungen aus dem mathematischen Seminar* (1922+); *Zeitschrift für angewandte Mathematik und Mechanik* (1921+); and *Zeitschrift für mathematischen und naturwissenschaftlichen Unterricht* (1870+). Of historical interest are: *Acta Eruditorum* and *Supplementa* (1682–1734); *Nova Acta Eruditorum* and *Supplementa* (1732–76); *Mitteilungen zur Geschichte der Medizin und der Naturwissenschaften* (1902+); and *Archiv für die Geschichte der Naturwissenschaften und der Technik* (1909–22), continued as *Archiv für Geschichte der Mathematik, der Naturwissenschaften und der Technik* (1927+).

GREAT BRITAIN.—Among various early mathematical organizations is The Mathematical Society, founded by mathematicians of Spitalfields in 1717. It continued in existence till its absorption in 1845 by the Astronomical Society. (See *History of the Royal Astronomical Society 1820–1920*, London, 1923, pp. 99–104; A. DeMorgan, *Budget of Paradoxes*, second ed., Chicago, 1915, vol. 1, pp. 374–383; *The Articles of the Mathematical Society meeting . . . in Brown's Lane, Spitalfields . . .* (*A Catalogue of the books belonging to the Society*), London, 1784 and 1821.) The London Mathematical Society, founded in 1865, has about 400 members. Its publications are *Proceedings* (1866+) and *Journal* (1926+). The Edinburgh Mathematical Society (about 275 members) was founded in 1883, and has published *Proceedings* (1884+) and *Mathematical Notes* (1909+). The Mathematical Association (about 1,160 members) was founded in 1871 as The Association for the Improvement of Geometrical Teaching, and took its present name in 1897. It has published *Reports* (1871–93) and *Mathematical Gazette* (1894+).

Material of importance for the mathematician is to be found in *Royal Society of London, Transactions* (1665+); *Cambridge Philosophical Society, Proceedings* (1843+) and *Transactions* (1820+); *Royal Society of Edinburgh, Proceedings* (1832+) and *Transactions* (1783+); *Cambridge Mathematical Journal* and *Cambridge and Dublin Mathematical Journal* (1837–54), continued as *The Quarterly Journal of Pure and Applied Mathematics* (1857+); *Messenger of Mathematics* (1871+), continuation of *Oxford, Cambridge and Dublin Messenger of Mathematics* (1862–71); *London, Edinburgh and Dublin Philosophical Magazine* (1798+) and *British Association for the Advancement of Science, Reports* (1836+). In *Nature* (1869+) there is much of interest.

Among many minor serials are: *Mathematical Questions and Solutions from "The Educational Times" with many Papers and Solutions* (1864–1916), continued with a slight change in title till 1918; *The Mathematician* (1843–50) (Davies); *Mathematical Repository* (1795–1804, 1806–35) (Leybourn). If *The Lady's*

Diary continued as *The Lady's and Gentleman's Diary* be regarded as a mathematical serial, it is the longest lived of all such serials being published for 168 consecutive years, 1704–1871.

GREECE.—The 'Ελληνιγὴ Μαθηματικὴ 'Εταιρεια (Greek Mathematical Society), with about 160 members, was founded at Athens in 1918 and *Bulletin de la Société Mathématique de Grèce*, Δελτιον 'Ελληνικῆs Μαθηματικησ 'Εταιρειαs, in Greek, has been published at Athens since 1919.

HOLLAND.—The oldest existing national mathematical society, Wiskundig Genootschap (about 243 members), was founded at Amsterdam in 1778. Associated with its name on its various publications, and as a part of the title, is the motto: "Een onvermoeide arbeid komt alles te boven" ("Unwearying toil conquers everything"). The Society's chief recent publications are: *Wiskundige Opgaven met de Oplossingen* (1855+); *Nieuw Archief voor Wiskunde* (1875+) which was a continuation of *Archief* (1856–74), which continues the society's *Verslagen van het Verhandelde op de Wetenschappelijke Vergaderingen* (1844–1852); and *Revue Semestrielle des Publications Mathématiques* (1893+). Of at least eleven other earlier periodicals of the Society the earliest is *Kunst-Oeffeningen over verscheide nuttige Onderwerpen der Wiskunde* (1782–88). *See* M. Van Haeften, *Het Wiskundig Genootschap zijn oudste Geschiedenis, zijn Werkzaamheden en zijn Beteekenis voor het Vezekeringswezen* (Groningen, 1923).

There is important mathematical work in publications of the Amsterdam Academy of Sciences, *Afdeeling Natuurkunde:* (a) *Verhandelingen* (1854+); (b) *Verslagen* (1853+); and (c) *Proceedings* (1898+) mainly translated from the *Verslagen.*

Among elementary periodicals, which are very numerous, are: *Tijdschrift voor Wiskunde* (1874–77), Deventer; *Nieuw Tijdschrift voor Wiskunde* (1913+), Groningen; *Bijvoegsel van het Nieuw Tijdschrift voor Wiskunde* (1924–27) continued as *Euclides, Tijdschrift voor de Didactiek der Exacte Vakken* (1927+); *Christiaan Huygens* (1921+); and *Wiskundig Tijdschrift* (1904–21), Haarlem.

HUNGARY.—The chief older mathematical publications are of the Hungarian Academy of Sciences (Magyar Tudomanyos Akadémia) at Budapest. They are: *Mathematikai és Physikai Lapok* (1892+), *Mathematikai és Természettudomány Értesitö* (1882+), and *Mathematische und naturwissenschaftliche Berichte aus Ungarn* (1882+). A series of mathematical memoirs, *Értekezések a Mathematikai Tudomanyok Köréböl,* (1867–1894), is another valuable publication of the Akadémia. A recent important publication of the University of Szeged is *Acta Litterarum ac Scientiarum, Sectio Scientiarum Mathematicarum* (1922+). Intended for the secondary schools the periodical *Középiskolai Mathematikai Lapok,* Budapest (1893–1914), has been continued as *Középeskolai Mathematikai és Fizikai Lapok* (1925+).

INDIA.—The Calcutta Mathematical Society, founded in 1908 for the promotion of mathematical research, publishes a *Bulletin* (1909+). Since 1919 the University of Calcutta has published an annual volume, *Journal of the Department of Science,* which is devoted to original contributions in mathematics, chemistry, physiology, and botany. The Indian Mathematical Club (formerly The Analytic Club) was founded at Madras in 1907 and the first printed *Progress Report,* no. 7, appeared in 1908. This publication was followed by *The Journal of the Indian Mathematical Club* (1909–10), continued as *The Journal of the Indian Mathematical Society* (1911+).

ITALY.—The Circolo Matematico di Palermo, founded in 1884, has been both a national and an international organization, and now has about 584 members. Its chief publication has been its *Rendiconti* (1887+). The Unione Matematica Italiana was established as a national organization in 1922 and now has about 373 members. Its official organ is a *Bollettino* (1922+). The Circolo Matematico di Catania, of the University of Catania, was founded in 1921, and published *Note e Memorie* (1921–22), *Esercitazioni Matematiche* (1921–26), continued as *Note ed Esercitazioni Matematiche* (1927+).

The most important periodicals for mathematics, and among the most important in the world, are: *Annali di Matematica Pura ed Applicata* (1858+) a continuation of *Annali di Scienze Matematiche* (1850–57) which may possibly be regarded as a development of *Raccolta di Lettere ed altri Scritti intorno alla Fisica ed alle Matematiche* (1845–49); *R. Accademia dei Lincei,* Rome, *Rendiconti* (1884+), *Memorie* (1876+); and Prince Boncompagni's *Bullettino di Bibliografia e di Storia delle Scienze Matematiche e Fisiche* (1868–87), Rome. Among many other periodicals are: *R. Accademia delle Scienze dell' Istituto di Bologna, Memorie* (1850+) and *Rendiconto* (1829+); *Giornale di Matematiche* (1863+) (Battaglini); *R. Accademia delle Scienze Fisiche e Matematiche,* Naples, *Rendiconti* (1862+) and *Atti* (1864); *R. Accademia della Scienze di Torino, Atti* (1865+) and *Memoire* (1759+); University of Rome, *Facoltà di Scienze, Seminario Matematico, Rendiconti* (1914+); *Archivio di Storia della Scienza* (1919+); *Bollettino di Bibliografia e Storia delle Scienze Matematiche* (1898–1922) (Loria) continued as a supplement to the secondary school journal *Il Bollettino di Matematica* (1902+); *Periodico di Matematiche,* various titles (1886+) organ of Societa Italiana "Mathesis"; Istituto G. Ferraris, *Rassegna di Matematica e Fisica* (1920+), Rome; and *Giornale di Matematica Finanziaria* (1922+). *Scientia* (1907+) contains popular articles of value.

JAPAN.—The Physico-Mathematical Society of Japan (*Nippon Sûgaku-Buturigakkwai*) founded in 1884, has published proceedings (*Kizi,* 1884+), the first two volumes (1884–1887) being in Japanese, and the rest mainly in English. *The Tôhoku Mathematical Journal* (1911+) is now published by the Imperial University at Sendai. Under the auspices of the National Research Council of Japan have already been published (1924–28) five volumes of *The Japanese Journal of Mathematics, Transactions and Abstracts.* Two other English periodicals containing some advanced mathematical work are: *Science Reports, First series, Mathematics, Physics, Chemistry* (1912+) also published by the Imperial University at Sendai; and *Journal of the Faculty of Science, Imperial University of Tokyo, Section 1, Mathematics, Astronomy, Physics, Chemistry* (1925+). The latter is the continuation of *Journal of the College of Science, Imperial University at Tokyo* (1887–1925).

There is also *Journal of The Mathematical Association of Japan for Secondary Education,* in Japanese (title excepted) (1919+).

NORWAY.—The Norsk Matematick Forening, founded at Oslo in 1918, has as its official organ, *Norsk Matematisk Tidsskrift* (1919+). The Society is publishing also *Norsk Matematisk Forenings Skrifter* (1921+), and *Sophus Lie Gesammelte Abhandlungen* (1922+). *Archiv för Mathematik og Naturvidenskab* (1876+), Oslo, and *Norske Videnskabs-akademie i Oslo, Mathematisk-naturvidenskabelig Klasse, Skrifter* (1894+) contain some valuable mathematical material.

POLAND.—The Polskie Towarzystwo Matematyczne (Société Polonaise de Mathématique) was founded at Cracow in 1919, and one volume of *Rozprawy* (1921), in Polish, was published. This was continued by annual volumes (1922+) of *Rocznik* (*Annales*) in French. A Polish supplement (*Dodatek*) is also issued (1922+). Among the older periodicals are two published in Warsaw: *Prace Matematycznofizyczne* (1888+) and *Wiadmości Matematyczne* (1897+). A new Warsaw periodical of much importance, devoted entirely to the theory of aggregates, is *Fundamenta Mathematicá* (1920+). Another publication valuable for its mathematical material is *Akademija umiętjetności, Bulletin International,* Cracow (1889–1900), in French and German; *Bulletin International, Classe des Sciences Mathématiques et Naturelles, Série A* (1901+); and *Memoires, Classe des Sciences Mathématiques et Naturelles, Série A* (1928+).

PORTUGAL.—*Jornal de Sciencias Mathematicas e Astronomicas* (1877–1902), Coimbra, of the Academia Polytechnica do Porto, was continued as the Academia's *Annaes Scientificos* (1905–21), and then as *Anais da Faculdade de Sciências do Porto* (1927+). Under the auspices of the Accademia Real das Sciéncias de Lisboa, has been published *Jornal de Sciencias Mathematicas, Physicas e Naturaes* (1866+).

RUMANIA.—The Societatea "Gazeta Matematică," with about 110 members, was founded at Bucharest in 1909, and *Gazeta Matematica foae lunara de Matematici elementare si speciale pentru*

ugul Şçoalelor secundare, speciale şi superioare (1895+), became its official organ Among numerous minor mathematical serials of Rumania is the monthly *Revista Matematică din Timişoara* (1921+), published at Timişoara. Some advanced mathematical work has been published in *Bulletin Mathématique de la Société Roumaine des Sciences*, Bucharest (1892+); and *Académie Roumaine*, Bucharest, *Annales* (1867+), and *Section Scientifique, Bulletin* (1912+).

Russia.—At Moscow in 1864 was organized a Circle of lovers of mathematics which in 1867 developed into the important Moscow Mathematical Society (Moskovskoe Matematicheskoe Obshchestvo). This organization founded and carried on *Matematicheskiĭ Sbornik* (1866+). Another important society is Khar'kovskoe Matematicheskoe Obshchestvo, founded in 1879. Its *Communications* (*Soobshcheniia*) (1879–1918) were continued as *Annales Scientifiques des Institutions Savants de l'Ukraine, section mathématique* (1924–28) which were continued as *Communications de la Société mathématique de Kharkow* (1927+). A third society is at the University of Kazan, Fiziko-Matematicheskoe Obshchestvo, about 106 members, whose Bulletin (*Izviestiia*) (1891+) was the continuation of the physics-mathematics section (1880–90) of the society of naturalists of the University *Bibliographia Mathematica Rossica* (1896–1900) was a supplement to *Izviestiia*. A fourth society is Leningradskoe Fiziko-Matematiceskoe Obshchestvo, founded in 1892, and with about 80 members The first volume of *Journal de la Société Physico-Mathématique de Léningrade* appeared in 1927. Much of mathematical importance appears in the various publications of the Academy of Sciences, Leningrad (1726+).

Fiziko-matematicheskiia nauki v ikh nastoiashchem i proshedshem (1885–1905). edited and conducted by Bobynin was important for its bibliographical and historical articles and supplements.

South Africa.—Some mathematical papers are to be found in *Royal Society of South Africa, Transactions* (1908+), Cape Town; and in *South African Journal of Science* (1903+) of the South African Association for the Advancement of Science.

Spain.—The Sociedad Matematica Española founded at Madrid in 1910 published a *Revista* (1911–1917). This was continued (1919+) as *Revista Matematica Hispano-Americana*, published under the auspices of the Sociedad and of the Laboratorio y Seminario Matematico of the University. This Seminario has also issued some *Publicaciones* (1916+). The *R. Academia Española, Memorias* (1870+), Madrid, contains mathematical material.

Sweden.—*Acta Mathematica* (1882+), founded by Mittag-Leffler, one of the most important mathematical periodicals in the world, is edited by mathematicians of Sweden, Norway, Denmark and Finland, and is published by the Mathematical Institute, at Djursholm, of the Royal Academy of Sciences (K. Svenska Vetenskabsakademien), Stockholm. The Academy's *Arkiv för Matematik, Astronomi och Fysik* (1903+) is also of importance to the mathematician, as well as considerable mathematical material in its *Handlingar, Bihang til Handlingar, Årsbok*, and *Öfversigt*. *Svenska Aktuarieföreningens Tidskrift*, Upsala (1914–17), and *Skandinavisk Aktuarietidskrift*, Upsala (1918+) contain mathematical material of value.

To Sweden must also be credited *Bibliotheca Mathematica* (1884–1915) founded and edited by Eneström and, from 1888 on, the outstanding journal of its time for the history of mathematics. (*See* below under United States.)

Switzerland.—The Société Mathématique Suisse was founded in 1909 to promote mathematical research. The Société Suisse des Professeurs de Mathématiques, otherwise named earlier, and founded in 1900, is primarily for professors in the secondary schools. The activities of both organizations are set forth in the country's only separate mathematical periodical, *L'Enseignement Mathématique, méthodologie et organization de l'enseignement, philosophie et histoire des mathématiques, chronique scientifique, mélanges bibliographie* (1899+), Paris and Geneva. In addition to its serials the Schweizerische Naturforschende Gesellschaft (founded 1815) publishes Euler's *Opera Omnia* of which 22 volumes have already appeared (1911+). Other sources where material of interest, some of high order, may be found, are: *Vierteljahrschrift der naturforschenden Gesellschaft in Zürich* (1856+); *Mitteilungen der naturforschenden Gesellschaft in Bern* (1843+); *Verhandlungen der naturforschenden Gesellschaft in Basel* (1852+); and *Bulletin de la Société Vaudoise des Sciences Naturelles* (1842+), Lausanne.

United States.—The New York Mathematical Society, founded in 1888, developed into the American Mathematical Society (1894) which now has about 1,800 members, and is dedicated to promoting mathematical research. The *Bulletin of the New York Mathematical Society* (1891–94) was continued as *Bulletin of the American Mathematical Society* (1894+). The *Transactions of the American Mathematical Society* was established in 1900, and in 1927 the Society acquired an important share in editorial control of the *American Journal of Mathematics* (1878+), established by The Johns Hopkins University under Sylvester's direction. The Society has also published volumes on important topics of modern mathematics. The Mathematical Association of America, founded in 1915, and now having over 2,000 members, aspires particularly to serve the colleges of the country by awakening and sustaining interest in mathematics and by fostering the beginnings of mathematical research. Its official organ (1916+) is *The American Mathematical Monthly* (1894+) founded and published for many years by B. F. Finkel. *Bibliotheca Mathematica* (*see* under Sweden) was revived by the Association in 1929.

Other important mathematical publications are: *Annals of Mathematics* (1884+), a continuation of *The Analyst* (1874–83), published by the University of Virginia 1884–99, by Harvard University till 1912, and since then by Princeton University; and *Journal of Mathematics and Physics* (1921+) published by the Massachusetts Institute of Technology. Brief announcements of new results are to be found in *National Academy of Sciences, Proceedings* (1915+). Some valuable mathematical work is to be found in *University of California, Publications in Mathematics* (1912+); *Rice Institute Pamphlets* (1915+), Houston, Texas; *American Academy of Arts and Sciences, Proceedings* (1846+), *National Academy of Science, Memoirs* (1866+), and in *Isis* (1913+; not published between 1914 and 1919) the official organ of the History of Science Society. (*See* under Belgium.)

Mathematics Teacher (1908+) is the official journal (1921+) of the National Council of Teachers of Mathematics, organized in 1920, and now having about 5,000 members. It publishes also a *Yearbook* (1926+)

Bibliography.—Current journals grouped under countries of publication are listed in *International Catalogue of Scientific Literature, List of Journals*, 1903, and *Supplementary List of Journals*, 1904. But from the bibliographic point of view the great *Union List of Serials in Libraries of the United States and Canada*, New York, 1927, supersedes everything else of the kind. (R. C. A.)

MATHEMATICAL TABLES. The primary purpose of mathematical tables is to render the work of the professional computer in mathematics, engineering, astronomy, statistics, etc., less laborious than it would otherwise be. The arrangement and typography must be such that the minimum strain is imposed on the computer's eyes, for he may be called upon to use the table for hours at a stretch. The results tabulated are the "tabular results"; and the corresponding numbers, by which the table is entered, are the "arguments." A table is one of single or double entry, according as it has one or two arguments A table of logarithms of numbers is a table of single entry, the numbers being the "arguments" and the logarithms the "tabular results"; a simple multiplication table is one of double entry, giving the product xy as the "tabular result" corresponding to the "arguments" x and y.

The invention of logarithms in 1614 came as a great boon to computers (astronomers particularly), for it made calculations involving multiplications comparatively easy work. Since that time the majority of tables of special functions were, until quite recently, published giving the logarithmic instead of the natural values, but owing to the increasing utility of calculating machines, there is now a tendency to publish the natural values.

Notation.—In the description of tables the following contraction for the interval of the argument will be used. Instead of writing, for example, that "the logarithmic sines are given for every 10 seconds up to 45°, or from 0° to 45° at intervals of 10 seconds," the writer will use the contraction "logarithmic sines are given for 0° (10″) 45°." In general *n-place* table means one, in which the tabular results are exhibited to *n* decimal places.

Common or Briggsian Logarithms of Numbers.—This system of logarithms is used for most practical purposes. The fundamental work which contains the results of the original calculations is that of Briggs's *Arithmetica Logarithmica* (London, 1624); it gives the logarithms of the integers 1 to 20,000 and 90,000 to 100,000 to 14 decimal places with interscript differences. Briggs intended to publish the logarithms of the numbers 20,000–90,000 to 14 places, but before he completed this part of the table he was forestalled by De Decker in his *Tweede Deel der Nieuwe Telkonst* (Gouda, 1627) and Vlacq in his so-called *Editio Secunda* of Briggs's *Arithmetica* (Gouda, 1628), who gave the 10–decimal logarithms of integers 1–100,000 with differences. The tables of De Decker and Vlacq are identical, for the men were really partners in the speculation. For the majority of succeeding tables of logarithms of numbers, either the tables of Briggs or De Decker-Vlacq have been the sources, directly or indirectly. Very few recalculations have been made and for nearly 300 years the De Decker-Vlacq table, with its errors corrected, was the best 10-place table of the logarithms of numbers. In 1794 Vega published a reprint of Vlacq's table; this 10-place table, of which the arrangement is not so good as Vlacq's, is very useful and is still in general use. Although Vega bestowed great care on the detection of errors, there are a number of last figure errors. The title is *Thesaurus Logarithmorum Completus* (Leipzig). Three photographic reprints have been published, two at Florence by the *Istituto Geografico Militare* in 1889, 1896, and the third by Stechert of New York in 1923. In the last one the reproduction is very poor and all the errors of the original appear. Duffield's 10-place table (Washington, 1897) cannot be trusted, for, although he claims to have made a recalculation, practically all Vega's last figure errors appear. Peters in *Zehnstellige Logarithmentafel: Erster Band.* (Berlin, 1922) gives the 10-place logarithms of all numbers to 100,000 with first differences and an auxiliary table, which shows corrections for second differences. The table is the result of a new calculation.

In many problems 10-figure accuracy is not required, but in the above such tables have been described for they are the fundamental tables. A large number of tables exhibiting 4, 5, 6-place logarithms have been published. A good 6-place table is Bremiker's *Logarithmorum VI. Decimalium Nova Tabula.* (Berlin, 1852.) Several editions appeared with title page in German and English (1875). 7-place logarithms are frequently required and there are a considerable number of accurate and well-arranged tables, including those of Bremiker, Bruhns, Dupuis, Lalande, Sang, Schrön and Shortrede. Schrön's table *Siebenstellige Gemeine Logarithmen*—(Braunschweig, 1860) is typical. There have been editions in German, English and French. The arrangement is the best for a 7-place table and the modern editions are accurate. The figures of the logarithms are grouped 3, 4, the first group being printed only once. When a change occurs in the final figure of this leading group in the course of a row it is shown by an asterisk prefixed to all the groups affected in the row. This method of attracting the attention of the computer is very successful. In 1871 Sang published *A New Table of Seven-place Logarithms of Numbers from 20,000 to 200,000* (London). There is a distinct advantage in choosing this range in place of 10,000 to 100,000. For the latter range the differences at the commencement of the table change so rapidly that the proportional parts are so numerous that they are either very crowded or some of them are omitted; by making the table start from 20,000 the differences are halved in magnitude and there are one-fourth as many on a page. This table, unlike most 7-figure tables, is mainly the result of a new calculation. There are very few 8-place tables; until quite recent times there was only one such table—John Newton's *Trigonometria Britannica* (London, 1658), where the logarithms of numbers to 100,000 are given. The usual arrangement of 7-place tables is due to this Newton, viz., the first four figures of the argument are shown in the left hand margin, while the fifth figure is shown at the head of successive columns. The only other 8-place tables have been published since 1890; the Service Géographique de l'Armée (France) published an abridgement of the *Tables du Cadastre* (the famous French manuscript tables) under the title *Tables des Logarithmes à hûit décimales des nombres de 1 à 120,000* (Paris, 1891), and in the same year Mendizábal Tamborrel published *Tables des Logarithmes à hûit décimales des nombres de 1 à 125,000* (Paris). Bauschinger and Peters, as a result of an entirely new calculation to 12 places, published *Logarithmisch-trigonometrische Tafeln mit acht Dezimalstellen* (Leipzig, 1910). It has appeared with English title and preface. The logarithms to 8 decimals of all numbers to 200,000 may be taken from this directly.

It is sometimes necessary to use logarithms to a greater number of figures than 10, but owing to the great expense of publishing extensive tables to a large number of figures, several methods have been devised by mathematicians which enable a computer, with the help of a comparatively small table, to calculate the logarithm to the required number of figures. For example, Gray in *Tables for the Formation of Logarithms and Anti-Logarithms to twenty-four or any less number of places* (London, 1876), explains a method by which the logarithm and antilogarithm can be found to any number of places not greater than 24. Similar tables and methods have been published by Börgen, Steinhauser, Guillemin, Mansion-Namur, Pineto, Andoyer and Ellis. At present there is in progress an extensive table to 20-decimals, the calculations being carried out by Thompson. The first part appeared in 1924 to commemorate the Tercentenary of Briggs's publication of *Arithmetica Logarithmica* under the title *Logarithmetica Britannica, being a Standard Table of Logarithms to Twenty Decimal Places* (Cambridge University Press, 1924). This part gives the logarithms of numbers 90,000 to 100,000; two more parts have been published since 1924.

Logarithmic Trigonometrical Functions.—The original and fundamental tables of the logarithmic trigonometrical functions are (1) Vlacq's *Trigonometria Artificialis* (Gouda, 1633), which exhibits log sines and tangents to every ten seconds of the quadrant to 10 decimal places with differences. (2) Briggs's *Trigonometria Britannica* (London, 1633), which gives the natural sines to 15 places, tangents and secants to 10 places, log sines to 14 places and tangents to 10 places at intervals of 0·001 degree from 0° to 45° with interscript differences. In Vlacq's earlier work of 1628 there are given, in addition to the logarithms of numbers, the log sines, tangents and secants for every minute of the quadrant to 10 places with differences. The majority of the logarithmic-trigonometrical tables published since 1633 have been calculated from, or are abridged forms of the tables of Briggs and Vlacq. It is to be noted that Vlacq used the sexagesimal division of the degree, while Briggs used the centesimal division. This step of Briggs was important and it is probable that, if Vlacq's table had not been published in the same year, tables published subsequently might have used the latter division, and thus ensured a saving of work in interpolations, multiplications, etc. The French mathematicians at the end of the 18th century divided the right angle centesimally, but there is no real advantage in doing this. Michael Taylor in *Tables of Logarithms* (London, 1792) made a big advance by giving log sines and tangents to *every second* of the quadrant to 7 places. This table was calculated by interpolation from Vlacq's *Trigonometria* to 10 places and then cut down to 7, so that the table should be accurate to the last figure. This table is in inconvenient arrangement. Bagay's *Nouvelles Tables Astronomiques et Hydrographiques* (Paris, 1829) has always been preferred. This also gives a complete logarithmic trigonometrical canon to every second.

Many collections of tables give the logarithmic trigonometrical canon to 7 places (*e.g.*, Schrön, Bruhns, etc.) for every sexagesimal minute, or for every 10 sexagesimal seconds, or for every centesimal minute, or for every 10 centesimal seconds. Bauschinger and Peters (Leipzig, 1911) in *Logarithmisch-trigonometrische Tafeln*

Log e^x.—The most extensive table is that of Glaisher, *Camb. Phil. Trans.* XIII., 1883, which exhibits the values to 10 places for (i) $x=0.000(0.001)0.100$, (ii.) $0.00(0.01)2.00$, (iii.) $0.0(0.1)10.0(1.0)500$. Becker and Van Orstrand give 7-place values for $x=0.000(0.001)3.00(0.01)6.00$. e^{-x} is given in an extensive table by Newman, *Camb. Phil. Trans.* XIII. (1883) to 18 places for $x=0.000(0.001)15.350$; to 14 places for $x=15.350(0.002)17.300(0.005)27.635$. It is given by Becker and Van Orstrand for the same range and accuracy as $\log e^x$. In the *Camb. Phil. Trans.* (1883) Glaisher also gives e^x to 9 figures for the same arguments as $\log e^x$. In the *Tables of the Exponential Functions* (Washington, 1913) Van Orstrand gives e^x and e^{-x} to 20 places for $x=0.0(0.1)32.0$.

Tables of Some of the Higher Mathematical Functions.—The majority of such tables are of limited range and have generally been calculated for some special purpose. They appear in a few collections of tables to 4 or 5 places, but more usually in the journals of scientific societies to a larger number of places.

Probability Integral.—There are a considerable number of small tables of this integral, particularly in collections of tables for statisticians; there is a certain amount of variation in the actual form of the integral tabulated. Burgess, *On the Definite Integral* $\frac{2}{\sqrt{\pi}}\int_0^t e^{-t^2}\,dt$ (Edinburgh, 1898) gives a number of references to existing tables. His main table exhibits the 9-decimal values of the function for $t=0.000\ (0.001)\ 1.250$ with first and second differences and $\frac{2}{\sqrt{\pi}}e^{-t^2}$ to 9 decimals; also $\frac{2}{\sqrt{\pi}}\int_0^t e^{-t^2}\,dt\frac{2}{\sqrt{\pi}}e^{-t^2}$ to 15 places with first four differences for $t=1.000(0.001)1.500(0.002)3.000(0.1)5(0.5)6.0$. When great accuracy is not required, the 4-place tables of Jahnke and Emde, *Funktiontafeln* (Leipzig, 1909) may be used. Useful tables are given in *Tables for Statisticians* (Pearson). The first table of this integral is given in the form $\int_t^\infty e^{-t^2}\,dt$ by Kramp in his *Analyse des Réfractions* (Strassburg, 1798), to 8 places for $t=0.00(0.01)2.00$ and to 11 places for $t=2.00(0.01)3.00$. A similar table appears in De Morgan's *Theory of Probabilities,* where there is also a 7-place table for $\frac{2}{\sqrt{\pi}}\int_0^t e^{-t^2}\,dt$ for $t=0.00(0.01)2.00$. Markoff in *Tables des valeurs de l'integrale* $\int_x^\infty e^{-t^2}\,dt$ (St. Petersburg, 1888), gives 11-place values with first four differences for $x=0.00(0.01)4.80$.

Legendre Coefficients or Zonal Harmonics.—The values of $P_n(x)$ for $x=0(0.01)1.00$, $n=1(1)7$ are given by Glaisher in *Brit. Assoc. Rep.* (1879). They are reproduced by Dale and Jahnke-Emde. $P_n(\cos\theta)$ for $n=1(1)7$ and $\theta=0°(1°)90°$ are given to 4 places by Perry, *Proc. Phys. Soc.* (1892) and *Phil. Mag.* (1891); also in Jahnke-Emde. Extensive tables have been published by Tallquist at Helsingfors, 1908.

Bessel Functions.—The work of Jahnke and Emde referred to above contains a list of all tables before 1909 connected with Bessel Functions, and also some 4-place tables. The majority of tables of these functions are scattered through the journals of mathematical and scientific societies. Hansen's extension of Bessel's tables is reproduced by Schlömilch in *Zeitschr. für Math.* (1868) and by Lommel in *Studien über die Bessel'schen Functionen* (1868). This is a 7-place table of $J_0(x)$ and $J_1(x)$ for $x=0$ to 20 at intervals of 0.01. These functions to 12 decimals are given by Gray and Mathews as a reprint of the table of Meissel, *Abh. d. Berlin Akademie* (1888). In 1889 the Committee of the British Association for the Calculation of Tables decided to commence work on the tables of Bessel Functions and the first extensive table appeared in 1893, giving $I_1(x)$ to 9 places with first differences for $x=0.000(0.001)5.100$; $I_0(x)$ followed in 1896. Further tables appeared in the Reports of this Committee in 1907, 1909 and 1911 [also Neumann Functions $G_n(x)$ and $Y_n(x)$], 1912 (*ber x* and *bei x*), 1913 and later. In *Proc. Roy. Soc.* (1899) Aldis, "On the numerical computation of the functions $G_0(x)$, $G_1(x)$ and $J_n(x)$" gives a number of tables to 21 places for $x=0.0(0.1)6.0$.

Elliptic and Other Functions.—The Committee of the British Association (Mathematical Tables) commenced work on the elliptic functions in 1911 and tables appeared in the Reports of 1911–12–13–19. In the Report of 1924, tables of the Lommel-Weber and Bessel-Clifford functions are given.

Legendre, *Traité des fonctions elliptiques* (1826), gives a number of tables of the elliptic functions of the first and second kind and 4-place tables appear in the Jahnke-Emde collection.

q-Tables.—$\log_{10} q$ from $\theta=0°$ to $90°$ has been tabulated by Glaisher in *Month. Not. R. A. Soc.* (1877) for every degree to 10 places; Jacobi, *Crelle's Journal,* XXVI., for every tenth of a degree to 5 places; Bertrand, *Calcul Intégral* (1870), for every 5 minutes to 5 places and Meissel, *Sammlung mathematischer Tafeln* (Iserlohn, 1860) for every minute to 8 places.

Tables of integrals such as $Si\,x=\int_0^x\frac{\sin x}{x}dx$, $Ci\,x=\int_0^x\frac{\cos x}{x}dx$, $Ei\,x=\int_0^x\frac{e^x}{x}dx$, $Li\,x=\int_0^x\frac{dx}{\log x}$, have also been published. The Jahnke-Emde collection contains tables of the first three integrals to 4 places; Glaisher *Phil. Trans.* (1870), p. 367, gives *Si x, Ci x, Ei x* to 18 places for $x=0.00(0.01)1.0$, and to 11 places for $x=1(0.1)5(1)15(5)20$. *Ei x* is also given by Bretschneider in *Grunert's Archiv* III., p. 33 to 20 places for $x=1(1)10$ and for $x=10(1)20$ by Gram in *Publications of the Copenhagen Academy* (1884). The latter extends Glaisher's table in some places, giving *Ei x* for $x=5.0(0.2)20.0$ to 8, 9 or 10 places. *Li x* has been published by Glaisher in his *Factor Tables* (1883) to the nearest integer for $0(50{,}000)9{,}000{,}000$. Tables of the integrals are of limited extent.

Fresnel Integrals.—In the *Brit. Assoc. Report* (1926) $C(x)$ and $S(x)$ were tabulated to 6 places for $x=0.0(0.1)20.0$. Lommel, *Abh. Münch. Akademie* (1880), gives the values for $z=0(1)50$, where the integral $C(x)=\int_0^x\cos\frac{1}{2}\pi x^2dx$ is written in the form $\frac{1}{\sqrt{(2\pi)}}\int_0^z\frac{\sin z}{z}dz$. A 4-place table appears also in Jahnke-Emde.

Pearson Integral.—The integral $F(r,n)=e^{-\frac{1}{2}\pi n}\int_0^\pi \sin^r x\,e^{nx}\,dx$ which is required in certain statistical work has been tabulated in the form $\log F(r,\phi)$ where $n=r\tan\phi$, in *Brit. Assoc. Reports* (1896) and (1899), for successive integral values of r to 50, to 7 places. Tables of associated integrals appear in *Tables for Statisticians.*

References.—Glaisher, "Report on Mathematical Tables," *Brit. Assoc. Report* (1873); De Morgan, "Mathematical Tables," *English Cyclopaedia* (1861), vol. vii.; Mehnke, "Numerisches Rechnen," *Encyk der Math. Wiss.* (Leipzig, 1900–04), vol. i., pt. ii., pp. 941–1079; Horsburgh, *Modern Instruments and Methods of Calculation* (Edinburgh, 1915), pp. 47–60; Henderson, *Bibliotheca Tabularum Mathematicarum, being a descriptive catalogue of mathematical tables, Part I. Logarithmic Tables* (Cambridge University Press, 1926) (in progress).

(JA. H.)

MATHEMATICS, FOUNDATIONS OF. No proposition of mathematics is considered to be established until it has been *proved*—that is to say, logically deduced from other propositions previously established. But obviously this process of proof must begin somewhere; we must make some assumptions in order to start at all; and the problem arises, "What are the fundamental assumptions or *axioms* from which all the propositions of this subject can be deduced?"

With regard, for instance, to Euclidean Geometry, this problem has been solved; it is found that all geometrical terms, such as circle or parallelogram, can be defined in terms of a few *indefinables,* such as "point" and "straight line," and all the propositions of geometry can be deduced from a relatively small number of axioms about these indefinables, such as that through any two points passes one and only one straight line. When this has been done, we naturally want to discover whether these axioms are true. The answer to this question lies with the physicist; all that the mathematician can say is that if the axioms are true, then all the rest of geometry will be true also.

It is therefore clear that the mathematician asserts the propo-

sitions of geometry, not as absolute truths, but merely as implied by the axioms; and that, regarded as a branch of mathematics, geometry has no essential reference to physical space. For we can say, not only of physical points and planes but also of any classes of things which we may call points and planes, that *if* they obey the axioms of geometry, they obey the conclusions also.

So the mathematician regards geometry as simply tracing the consequences of certain axioms dealing with undefined terms, which are really variables in the ordinary mathematical sense, like x and y. And he demands of his axioms, not that they should be true on some particular physical interpretation of the undefined terms, but merely that they should be *consistent* with one another. If they were inconsistent this would probably appear from contradictory consequences being deduced from them; but although we had not as yet deduced any contradictory consequences, we could not therefore be sure that the assumptions were compatible with one another; for the latent contradiction might only become manifest after more elaborate deductions. The only way to provide positive proof is to find an interpretation of the undefined terms which will make the axioms true, since, if there are actual things for which they are true, the axioms must certainly be consistent. The things used for this purpose must not be taken from the physical world, or our proof would be subject to all the doubts and reservations of the experimental method. In fact, if the proof of consistency is to be a mathematical one, the entities which our undefined terms are interpreted to mean can only be taken from some other branch of mathematics. In the case of geometry we use the *real numbers* of algebra and analysis; for, if "point" be taken to mean ordered triad of numbers (x, y, z) and "plane" to mean set of such ordered triads satisfying a linear equation, and so on, it follows from the theory of real numbers that on this interpretation the axioms of geometry will be true, provided the theory of real numbers can be assumed.

Numbers.—We are thus thrown back to the theory of real numbers, for which we can again lay down axioms, using "real numbers" as a variable or undefined term meaning any things for which the axioms are true. If we proceed in this way we shall not, of course, have definite things called real numbers to use, as explained above, in showing the axioms of geometry consistent; but we shall still be able to prove that if the axioms about real numbers are compatible, so are those of geometry; and our next step will be to investigate, for their own sake and for the sake of geometry, the consistency of the axioms about real numbers.

This, in turn, we can establish by giving them a particular interpretation in terms of the rational numbers or fractions (the real numbers include also surds and other irrationals), and so indirectly in terms of the natural numbers 0, 1, 2, 3 . . . etc. For the natural numbers, again, a system of axioms has been laid down by Peano, in which the undefined terms are "number," "zero" and "successor," and a proof may again be demanded of their compatibility. But now there is no simpler branch of mathematics in which to interpret them; for with natural numbers we seem to have reached the most primitive mathematical material.

But apart from this difficulty about the consistency of the axioms on which depends, as we have seen, the proof of the consistency of the axioms of all other branches of mathematics, there is a further reason for being dissatisfied with the axiomatic treatment of the natural numbers. For if we adopt it, we shall be meaning by "numbers" any things that satisfy these axioms; whereas, in fact, there seems to be one definite meaning of number which is of peculiar importance and of which we should expect the mathematician to give an account. For instance, if I say that I have 2 pennies in my pocket, I there use "2" in a definite sense which we all understand. I do not mean by it merely something satisfying certain axioms, because it is easy to see that any axioms satisfied by the series of natural numbers must also be satisfied by, for instance, the numbers from 100 onwards; so that a purely axiomatic treatment of number would not enable us to distinguish between having 2 pennies in our pocket and having 102. Nor is it open to the mathematician to put this distinction aside as belonging to physics or some other branch of science, because he himself needs it in his own mathematical work, since he not only deals with the numbers as things about which he is talking, *i.e.*, as substantives, but also uses them as adjectives in just the ordinary sense. When he says, for instance, that a quadratic equation has *two* roots, the two in "two roots" is the same two as that in "two pennies," and it is essential to realize the difference between it and 102, a difference which depends on the individual natures of the numbers and not merely on the axioms they satisfy. (*See* NUMBER.)

Mathematics and Logic.—We are therefore led to investigate *cardinal numbers*—the kind of numbers that answer the question "How many?"—and by discovering what these are, we shall be able to prove the consistency of Peano axioms. The cardinal numbers bring us to *logic;* they belong to the terms which we use in any sort of reasoning, such as "all," "some," "not," "or," "class" and "relation"; and Frege has shown that they could in fact be defined in terms of these simpler logical notions, so that to give a clear account of the cardinal numbers and provide a basis from which to deduce their properties, we must make an investigation of formal logic.

This is also indispensable for another reason; we have so far discussed the axioms from which geometry, for instance, can be deduced, but said nothing about the methods of deduction, such as the principle of *reductio ad absurdum*, which belong to formal logic, but are as much presupposed in the validity of geometry as are the axioms themselves. These principles of deduction can be set out as propositions, containing no notions except the purely logical ones referred to above; and they can then themselves be made the subject of logical deductions. The propositions of formal logic can, in fact, all be deduced from a small number of primitive propositions, using only two or three particularly simple principles of deduction, *e.g.*, if p is true and p implies q, then q is true.

This leads to a complete merging of mathematics in formal logic; all mathematical propositions can be stated in purely logical terms and deduced from the primitive propositions of logic (terms such as "point" and "plane" being, as explained above, simply replaced by variables). The cardinal numbers can also be defined in purely logical terms and their properties can be similarly established. It can incidentally be shown that they satisfy Peano's axioms (provided we assume what is called the Axiom of Infinity). But it is no longer necessary to give these axioms, or those for real numbers, a fundamental place in our system of analysis. It is simpler to define the real numbers as definite entities constructed from the cardinal numbers in a definite way, and not merely to regard them as any things satisfying certain axioms.

The Paradoxes.—This reduction of mathematics to formal logic was first projected by Frege and was actually carried out by Whitehead and Russell in their *Principia Mathematica* (1910). It was, however, faced with various difficulties which were not altogether overcome, so that no system has been provided which finds general acceptance. These difficulties arise from the so-called Paradoxes of the Theory of Aggregates, which are cases in which it seems possible to give logical or mathematical proofs leading to each of two contradictory conclusions, a result which is intolerable to the mathematician as it overthrows his science altogether. Many instances of this seem to be mere quibbles, but more complicated ones cannot easily be distinguished from ordinary mathematics. An easy illustration is provided by the following example, non-mathematical. The word "short" is a short word, but the word "long" is not a long word. This suggests a division of adjectives according as they do or do not have the property which they connote. Words like "short" which apply to themselves let us call autological; and words like "long" which do not apply to themselves let us call heterological. Now suppose we put the question, "Is the word 'heterological' a heterological word?" Then we at once obtain contradictory answers. For if it is heterological, that means that it does not apply to itself, *i.e.*, that it is not heterological; but if it is not heterological, then it does apply to itself, *i.e.*, it is heterological.

In order to escape these contradictions Whitehead and Russell invented the Theory of Types, of which the essential idea is that a sentence which is perfectly grammatical English may yet be literally nonsense. To say that a class, *e.g.*, the class of things

quired sum and product of the cardinal numbers in question.

With these definitions it is now possible to *prove* the following six premises applying to finite cardinal numbers, from which Peano[1] has shown that all arithmetic can be deduced:—

i. Cardinal numbers form a class. ii. Zero is a cardinal number. iii. If a is a cardinal number, $a+1$ is a cardinal number. iv. If s is any class and zero is a member of it, also if when x is a cardinal number and a member of s, also $x+1$ is a member of s, then the whole class of cardinal numbers is contained in s. v. If a and b are cardinal numbers, and $a+1=b+1$, then $a=b$. vi. If a is a cardinal number, then $a+1=0$.

It may be noticed that (iv.) is the familiar principle of mathematical induction. Peano in an historical note refers its first explicit employment, although without a general enunciation, to Maurolycus in his work, *Arithmeticorum libri duo* (Venice, 1575).

But now the difficulty of confining mathematics to being the science of number and quantity is immediately apparent. For there is no self-contained science of cardinal numbers. The proof of the six premises requires an elaborate investigation into the general properties of classes and relations which can be deduced by the strictest reasoning from our ultimate logical principles. Also it is purely arbitrary to erect the consequences of these six principles into a separate science. They are excellent principles of the highest value, but they are in no sense the necessary premises which must be proved before any other propositions of cardinal numbers can be established. On the contrary, the premises of arithmetic can be put in other forms, and, furthermore, an indefinite number of propositions of arithmetic can be proved directly from logical principles without mentioning them. Thus, while arithmetic may be defined as that branch of deductive reasoning concerning classes and relations which is concerned with the establishment of propositions concerning cardinal numbers, the introduction of cardinal numbers makes no great break in this general science. It is merely a subdivision in a general theory.

Nature of Ordinal Numbers.—We must first understand what is meant by "order," that is, by "serial arrangement." An order of a set of things is to be sought in that relation holding between members of the set which constitutes that order. The set viewed as a class has many orders. Thus the telegraph posts along a certain road have a space-order very obvious to our senses; but they have also a time-order according to dates of erection, perhaps more important to the postal authorities who replace them after fixed intervals. A set of cardinal numbers has an order of magnitude, often called *the* order of the set because of its insistent obviousness to us; but, if they are the numbers drawn in a lottery, their time-order of occurrence in that drawing also ranges them in an order of some importance. Thus the order is defined by the "serial" relation. A relation (R) is serial[2] when (1) it implies diversity, so that, if x has the relation R to y, x is diverse from y; (2) it is transitive, so that if x has the relation R to y, and y to z, then x has the relation R to z; (3) it has the property of connexity, so that if x and y are things to which any things bear the relation R, or which bear the relation R to any things, then *either* x is identical with y, *or* x has the relation R to y, *or* y has the relation R to x. These conditions are necessary and sufficient to secure that our ordinary ideas of "preceding" and "succeeding" hold in respect to the relation R. The "field" of the relation R is the class of things ranged in order by it. Two relations R and R′ are said to be ordinally similar, if a one-one relation holds between the members of the two fields of R and R′, such that if x and y are any two members of the field of R, such that x has the relation R to y, and if x' and y' are the correlates in the field of R′ of x and y, then in all such cases x' has the relation R′ to y', and conversely, interchanging the dashes on the letters, *i.e.*, R and R′, x and x', etc. It is evident that the ordinal similarity of two relations implies the cardinal similarity of their fields, but not conversely. Also, two relations need not be serial in order to be ordinally similar; but if one is serial, so is the other. The relation-number of a relation is the class whose members are all those relations which are ordinally similar to it. This class will include the original relation itself. The relation-number of a relation should be compared with the cardinal number of a class. When a relation is serial its relation-number is often called its serial type. The addition and multiplication of two relation-numbers is defined by taking two relations R and S, such that (1) their fields have no terms in common; (2) their relation-numbers are the two relation-numbers in question, and then by defining by reference to R and S two other suitable relations whose relation-numbers are defined to be respectively the sum and product of the relation-numbers in question. We need not consider the details of this process. Now if n be any finite cardinal number, it can be proved that the class of those serial relations, which have a field whose cardinal number is n, is a relation-number. This relation-number is the ordinal number corresponding to n; let it be symbolized by $\dot{n}$. Thus, corresponding to the cardinal numbers 2, 3, 4 . . . there are the ordinal numbers $\dot{2}$, $\dot{3}$, $\dot{4}$. . . . The definition of the ordinal number 1 requires some little ingenuity owing to the fact that no serial relation can have a field whose cardinal number is 1; but we must omit here the explanation of the process. The ordinal number $\dot{0}$ is the class whose sole member is the null relation—that is, the relation which never holds between any pair of entities. The definitions of the finite ordinals can be expressed without use of the corresponding cardinals, so there is no essential priority of cardinals to ordinals. Here also it can be seen that the science of the finite ordinals is merely a subdivision of the general theory of classes and relations.

Cantor's Infinite Numbers.—Owing to the correspondence between the finite cardinals and the finite ordinals, the propositions of cardinal arithmetic and ordinal arithmetic correspond point by point. But the definition of the cardinal number of a class applies when the class is not finite, and it can be proved that there are different infinite cardinal numbers, and that there is a least infinite cardinal, now usually denoted by $\aleph_0$, where $\aleph$ is the Hebrew letter aleph. Similarly, a class of serial relations, called *well-ordered* serial relations, can be defined, such that their corresponding relation-numbers include the ordinary finite ordinals, but also include relation-numbers which have many properties like those of the finite ordinals, though the fields of the relations belonging to them are not finite. These relation-numbers are the infinite ordinal numbers. The arithmetic of the infinite cardinals does not correspond to that of the infinite ordinals. The theory of these extensions of the ideas of number is dealt with in the article NUMBER. It will suffice to mention here that Peano's fourth premise of arithmetic does not hold for infinite cardinals or for infinite ordinals. Contrasting the above definitions of number, cardinals and ordinals, with the alternative theory that number is an ultimate idea incapable of definition, we find that our procedure exacts greater attention and less credulity.

The Data of Analysis.—Rational numbers and real numbers in general can now be defined according to the same general method. If m and n are finite cardinal numbers, the rational number m/n is the relation which any finite cardinal number x bears to any finite cardinal number y when $n \times x = m \times y$. Thus the rational number one, which we will denote by 1_r, is not the cardinal number 1; for 1_r is the relation 1/1 as defined above, and is thus a relation holding between certain pairs of cardinals. Similarly, the other rational integers must be distinguished from the corresponding cardinals. The arithmetic of rational numbers is now established by means of appropriate definitions, which indicate the entities meant by the operations of addition and multiplication. But in order to obtain general enunciations of theorems without exceptional cases, mathematicians employ entities of ever-ascending types of elaboration. These entities are not created but are employed by mathematicians, and their definitions should show the construction of the new entities in terms of the old. The real numbers, including irrational numbers, have now to be defined. Consider the serial arrangement of the rationals in their order of magnitude. A real number is a class (α, say) of rational numbers which satisfies the condition that it is the same as the class of those rationals each of which precedes at least one member of α. Thus,

[1] Cf. *Formulaire mathématique* (Turin, ed. of 1903); earlier formulations of the bases of arithmetic are given by him in the editions of 1898 and of 1901. The variations are only trivial.

[2] *Cf.* Russell, *loc. cit.*, pp. 199–256.

consider the class of rationals less than 2_r; any member of this class precedes some other members of the class—thus 1/2 precedes 4/3, 3/2 and so on; also the class of predecessors of predecessors of 2_r is itself the class of predecessors of 2_r. Accordingly this class is a real number; it will be called the real number 2_R. Note that the class of rationals less than or equal to 2_r is not a real number. For 2_r is not a predecessor of some member of the class. In the above example 2_R is an integral real number, which is distinct from a rational integer, and from a cardinal number. Similarly, any rational real number is distinct from the corresponding rational number. But now the irrational real numbers have all made their appearance. For example, the class of rationals whose squares are less than 2_r satisfies the definition of a real number; it is the real number $\sqrt{2}$. The arithmetic of real numbers follows from appropriate definitions of the operations of addition and multiplication. Except for the immediate purposes of an explanation, such as the above, it is unnecessary for mathematicians to have separate symbols, such as 2, 2_r and 2_R, or 2/3 and $(2/3)_R$. Real numbers with signs (+ or −) are now defined. If a is a real number, $+a$ is defined to be the relation which any real number of the form $x+a$ bears to the real number x, and $-a$ is the relation which any real number x bears to the real number $x+a$. The addition and multiplication of these "signed" real numbers is suitably defined, and it is proved that the usual arithmetic of such numbers follows. Finally, we reach a complex number of the nth order. Such a number is a "one-many" relation which relates n signed real numbers (or n algebraic complex numbers when they are already defined by this procedure) to the n cardinal numbers 1, 2 ... n respectively. If such a complex number is written (as usual) in the form $x_1e_1+x_2e_2+\ldots+x_ne_n$, then this particular complex number relates x_1 to 1, x_2 to 2, ... x_n to n. Also the "unit" e_1 (or e_s) considered as a number of the system is merely a shortened form for the complex number $(+1)e_1+0e_2\ldots+0e_n$. This last number exemplifies the fact that one signed real number, such as 0, may be correlated to many of the n cardinals, such as 2 ... n in the example, but that each cardinal is only correlated with one signed number. Hence the relation has been called above "one-many." The sum of two complex numbers $x_1e_1+x_2e_2+\ldots+x_ne_n$ and $y_1e_1+y_2e_2+\ldots+y_ne_n$ is always defined to be the complex number $(x_1+y_1)e_1+(x_2+y_2)e_2+\ldots+(x_n+y_n)e_n$. But an indefinite number of definitions of the product of two complex numbers yield interesting results. Each definition gives rise to a corresponding algebra of higher complex numbers. We will confine ourselves here to algebraic complex numbers—that is, to complex numbers of the second order taken in connection with that definition of multiplication which leads to ordinary algebra. The product of two complex numbers of the second order—namely, $x_1e_1+x_2e_2$ and $y_1e_1+y_2e_2$, is in this case defined to mean the complex $(x_1y_1+x_2y_2)\ e_1+(x_1y_2+x_2y_1)e_2$. Thus $e_1\times e_1=e_1$, $e_2\times e_2=-e_1$, $e_1\times e_2=e_2\times e_1=e_2$. With this definition it is usual to omit the first symbol e_1, and to write i or $\sqrt{-1}$ instead of e_2. Accordingly, the typical form for such a complex number is $x+yi$, and then with this notation the above-mentioned definition of multiplication is invariably adopted. The importance of this algebra arises from the fact that in terms of such complex numbers with this definition of multiplication the utmost generality of expression, to the exclusion of exceptional cases, can be obtained for theorems which occur in analogous forms, but complicated with exceptional cases, in the algebras of real numbers and of signed real numbers. This is exactly the same reason as that which has led mathematicians to work with signed real numbers in preference to real numbers, and with real numbers in preference to rational numbers.

DEFINITION OF MATHEMATICS

It has now become apparent that the traditional field of mathematics in the province of discrete and continuous number can only be separated from the general abstract theory of classes and relations by a wavering and indeterminate line. Of course a discussion as to the mere application of a word degenerates into the most fruitless logomachy. But on the assumption that "mathematics" is to denote a science well marked out by its subject matter and its methods, and that at least it is to include all topics habitually assigned to it, "mathematics" is employed in the general sense[1] of the "science concerned with the logical deduction of consequences from the general premises of all reasoning."

Geometry.—The typical mathematical proposition is: "If x, y, z . . . satisfy such and such conditions, then such and such other conditions hold with respect to them." By taking fixed conditions for the hypothesis of such a proposition a definite department of mathematics is marked out. For example, geometry is such a department. The "axioms" of geometry are the fixed conditions which occur in the hypotheses of the geometrical propositions. The special nature of the "axioms" which constitute geometry is considered in the article GEOMETRY: *Axioms*. It is sufficient to observe here that they are concerned with special types of classes of classes and of classes of relations, and that the connection of geometry with number and magnitude is in no way an essential part of the foundation of the science.

Classes and Relations.—We now must deduce the general properties of classes and relations from the ultimate logical premises. In the course of this process, some contradictions have become apparent. That first discovered is known as Burali-Forti's contradiction,[2] and consists in the proof that there both is and is not a greatest infinite ordinal number. But these contradictions do not depend upon any theory of number, for Russell's contradiction[3] does not involve number in any form. This contradiction arises from considering the class possessing as members all classes which are not members of themselves. Call this class w; then to say that x is a w is equivalent to saying that x is not an x. Accordingly, to say that w is a w is equivalent to saying that w is not a w. An analogous contradiction can be found for relations. It follows that a careful scrutiny of the very idea of classes and relations is required. Note that classes are here required in extension, so that the class of human beings and the class of rational featherless bipeds are identical; similarly for relations, which are to be determined by the entities related. Now a class in respect to its components is many. In what sense then can it be one? This problem of "the one and the many" has been discussed continuously by the philosophers.[4] All the contradictions can be avoided, and yet the use of classes and relations can be preserved as required by mathematics, and indeed by common sense, by a theory which denies to a class—or relation—existence or being in any sense in which the entities composing it—or related by it—exist. Thus, to say that a pen is an entity and the class of pens is an entity is merely a play upon the word "entity"; the second sense of "entity" (if any) is indeed derived from the first, but has a more complex signification. Consider an incomplete proposition, incomplete in the sense that some entity which ought to be involved in it is represented by an undetermined x, which may stand for any entity. Call it a propositional function; and, if ϕx be a propositional function, the undetermined variable x is the argument. Two propositional functions ϕx and ψx are "extensionally identical" if any determination of x in ϕx which converts ϕx into a true proposition also converts ψx into a true proposition, and conversely for ψ and ϕ. Now consider a propositional function $F\chi$ in which the variable argument χ is itself a propositional function. If $F\chi$ is true when, and only when, χ is determined to be either ϕ or some other propositional function extensionally equivalent to ϕ, then the proposition $F\phi$ is of the form which is ordinarily recognized as being about the class determined by ϕx taken in extension—that is, the class of entities for which ϕx is a true proposition when x is determined to be any one of them. A similar theory holds for relations which arise from

[1]The first unqualified explicit statement of *part* of this definition seems to be by B. Peirce, "Mathematics is the science which draws necessary conclusions" (*Linear Associative Algebra*, § i. [1870], republished in the *Amer. Journ. of Math.*, vol. iv. [1881]). But it will be noticed that the second half of the definition in the text—"from the general premises of all reasoning"—is left unexpressed. The full expression of the idea and its development into a philosophy of mathematics is due to Russell, *loc. cit.*

[2]"Una questione sui numeri transfiniti," *Rend. del circolo mat. di Palermo*, vol. xi. (1897) and Russell, *loc. cit.*, ch. xxxviii.

[3]*Cf.* Russell, *loc. cit.*, ch. x.

[4]Cf. *Pragmatism: a New Name for Some Old Ways of Thinking* (1907).

diplomacy lessened his power. After 1702, when Joseph Dudley became governor, he lost most of his political prestige. He was made a fellow of Harvard in 1690, but gave up this office in 1703 after his father had been ousted from the presidency of the college. He longed to be president himself, but those who opposed his conservative views on church polity, differed with him politically, or disliked his too dictatorial tone on public affairs, prevented his being chosen. He turned much of his attention to Yale which he hoped might remain a stronghold of Congregational orthodoxy now that Harvard was less strict, and in 1722 seems to have declined an offer of the presidency of the Connecticut college.

Perhaps his most tangible public service was his advocacy of inoculation for smallpox in 1721. He interested Dr. Zabdiel Boylston, and his fearless scientific attitude in the face of opposition did much to advance the new weapon against the disease.

In his own day his fame was international. He corresponded with several distinguished European scholars, was elected to the Royal Society in 1713, and the University of Aberdeen gave him an honorary degree in 1710. His contemporary reputation was based partly on his writings—he published some 450 works on history, science, biography and various aspects of theology and religion—most important of which is a collection of biographies and historical fragments bearing on the "church history of New England" and called the *Magnalia Christi Americana* (1702). In spite of manifest defects this was the most elaborate book of the kind thus far produced in the Colonies, and is still of great historical value It has also some real literary merit. In part, too, he was famous for his scholarship—which, judged by the standards of his time, was great—for his amazingly wide reading, for his preaching, for his interest in and knowledge of current science and for his zeal in promoting piety and religion.

Ever since 1728 Cotton Mather has been more celebrated than any other American Puritan. Part of his notoriety is based on the theory that he was to some extent personally responsible for the witchcraft prosecution at Salem in 1692. He believed in witchcraft, investigated cases of supposed diabolic possession, and wrote before 1700 several books on the subject, among them an account of some of the Salem trials. Thus he may have stimulated the popular excitement of 1692, but that he tried to do so or was malicious in intent is not shown by the evidence. He warned the witch judges that some of their methods were unfair, and was convinced that some of the victims were unjustly sentenced.

A conservative, he kept abreast of many of the newer ideas of his time, and grew in tolerance toward other sects than his own. In 1718 he helped to ordain a Baptist minister; in 1726 he boasted that his own church had admitted to communion members of other denominations. In his writing he achieved some admirable prose, though he was archaic in his love of learned allusions and quotations. Nervously sensitive, hot-tempered, too eager in controversy, he had traits of the fanatic; vanity and ambition were elements in his character. None the less, throughout his life he gave himself unsparingly for what he believed was the good, spiritual and material, of his fellow men. However much some aspects of his nature and methods may repel, one must respect the nobility of his motives and his devotion to an ideal. He married three times. Nine of his 15 children died young, and only two outlived him.

See Cotton Mather's *Diary*, ed. W. C. Ford (1911–12), and the biographies by Samuel Mather (1729), Barrett Wendell (1891, 1926), and A. P. Marvin (1892). For bibliography *see* J. L. Sibley, *Biographical Sketches of Harvard Graduates*, vol. iii. (1873–85), and *Cambridge History of American Literature*, vol. i. (1917–21); *see* also K. B. Murdock, ed., *Selections from Cotton Mather* (1926), which contains a biographical and critical introduction. Many of the numerous short articles on Mather's life and activities are in the *Proceedings* of the American Antiquarian Society and of the Massachusetts Historical Society, and in the *Publications* of the Colonial Society of Massachusetts. *See* also B. Wendell, *Cotton Mather, the Puritan Priest* (1926); R. P. and L. Boas, *Cotton Mather, Keeper of the Puritan Conscience* (N.Y., 1928). (K. B. M.)

MATHER, INCREASE (1639–1723), American Congregational minister and author, was the youngest son of Richard Mather (*q.v.*). Born in Dorchester on June 21, 1639, he graduated at Harvard in 1656, took his M.A. degree at Trinity college, Dublin, in 1658, and ministered to congregations at Great Torrington, Devonshire, at Guernsey, at Gloucester, and at Weymouth and Dorchester in Dorsetshire. He returned to Boston in 1661, and in the next year married Maria, daughter of the Rev. John Cotton. He became teacher of the Second church in Boston in 1664, licenser of the press in 1674, fellow of Harvard in 1675, and in 1685 president of the college. In 1688 he went to London as the emissary of some of the Massachusetts churches to try to regain the old colonial charter. In 1690 he was made one of the Colony's official agents in England. He stayed in London till 1692, interviewing James II., William III., Queen Mary, and many others influential in politics. He enlisted in his cause the good offices not only of his Puritan brethren but of Penn the Quaker and of Bishops Burnet and Tillotson, the Anglicans. The old charter was not restored, but Mather was instrumental in making some of the terms of the new charter of 1691 more favourable to the colonists than they might otherwise have been. The king allowed him to nominate the royal governor and the other officers for the first year under the new charter. Phips, the governor of Mather's choice, proved unpopular, as did the charter itself, so that in 1701 those who combated Mather's political views or envied his power forced him from the presidency of Harvard.

For the rest of his life he was less active in public affairs, but wrote much and remained a dominating figure in Congregational councils. In 1721 he joined the campaign for inoculation for smallpox, in spite of his age and heedless of popular opposition. He published more than 150 books, most of them theological, but a few dealing with history, biography, or, in part, with science. Among the more interesting to-day are his life of Richard Mather (1670), his political tracts written in 1688–93, his *Essay for the Recording of Illustrious Providences* (1684), a collection of narratives of strange happenings in New England with discussion of a few scientific topics, his *Brief History of the War with the Indians* (1676), and his account of the Indian wars in New England, *A Relation of the Troubles . . .* (1677). His *Cases of Conscience* (1693) displays his attitude toward the witchcraft trials of 1692, and it is probable that the appearance of this book did much to end convictions for witchcraft in Massachusetts.

Harvard developed during Mather's term of office; his agency in England had important historical results; and to the fame given him by these things was added that derived from his reputation as preacher and scholar. He manifested his interest in science by forming a scientific society in Boston in 1683. His large library reflected the wide range of his reading in politics, science, the classics and history, as well as in theology. His hot temper, his stout championing of his own doctrines—though he was more moderate in debate than most of his adversaries—and his reputed ambition made enemies, who were, however, always outnumbered at home and abroad by those who revered him as a leader. He grew in tolerance, and in 1718 helped to ordain a Baptist minister in Boston. On one occasion at least, members of other sects were admitted to communion in his church. Among his many friends were Richard Baxter, the great English Puritan, and the physicist, Robert Boyle. To them he seemed, as to most later historians, the most powerful man of his time in the Puritan Colonies.

BIBLIOGRAPHY.—*See* K. B. Murdock, *Increase Mather* (1925), for a detailed biography, with a list of Mather's writings and of sources of information about him. *See* also Cotton Mather, *Parentator* (1724); W. Walker, *Ten New England Leaders* (1901); and J. L. Sibley, *Biographical Sketches of Harvard Graduates*, vol. i. (1873–85). Likenesses of him are reproduced and discussed in K. B. Murdock, *The Portraits of Increase Mather* (1924). (K. B. M.)

MATHER, RICHARD (1596–1669), American Congregational minister, was born in Lowton, Lancashire, England. At 15 he began to teach at a grammar school at Toxteth Park, near Liverpool. In 1618 he attended Brasenose college, Oxford, for a few months, but in November became minister of the Toxteth chapel. His Puritan tendencies led the ecclesiastical authorities to silence him in 1634, and on Aug. 17 of the next year he arrived at Boston (Mass.). A year later he became teacher of the church at Dorchester, and held that office until his death on April 22, 1669. He was locally celebrated as a preacher, and his books on the principles of New England Congregationalism together with

his activity in colonial church councils made him one of the most famous New England Puritans of his day. He was one of the translators of *The Whole Booke of Psalmes* (1640), the "Bay Psalm Book" designed for use in colonial churches. His greatest achievement was a statement of the creed and polity of Massachusetts Congregationalism which, with but few alterations, was printed as *A Platform of Church Discipline* (1649). This, the "Cambridge Platform," was for years the basic document of his sect in Massachusetts. He was an active advocate of the "Half-Way Covenant," a plan which provided a modified form of church membership for those who were unable to meet the tests prescribed by the original Congregational polity.

By his first wife, Katharine Holt of Bury, whom he married in 1624, he had six sons, four of whom became ministers. His second wife was Sarah Cotton, widow of the Rev. John Cotton of Boston.

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MATHEW, THEOBALD (1790–1856), Irish temperance reformer, was born at Thomastown on Oct. 10, 1790. A member of the Capuchin order, he successfully conducted a temperance campaign at Cork, where he laboured for many years. His influence, great in Ireland, spread to England and America, and in 1847 he was granted a pension by Queen Victoria. He died at Queenstown on Dec. 8, 1856.

See J. F. Maguire, *Father Mathew, a Biography* (1863).

MATHEWS, CHARLES (1776–1835), English actor, was born in London on June 28, 1776. His father was "a serious bookseller," who also officiated as minister in one of Lady Huntingdon's chapels. Mathews was educated at Merchant Taylors' school. For several years, from 1794 onwards, Mathews played in Dublin. In May 1803 he made his first London appearance at the Haymarket as Jabel in Cumberland's *The Jew* and as Lingo in *The Agreeable Surprise*. From this time his professional career was an uninterrupted triumph. He was a simple and kind hearted man with a wonderful gift of mimicry. Mathews visited America in 1822 and in 1834. His last appearance in New York was on Feb. 11, 1835, when he played Samuel Coddle in *Married Life* and Andrew Steward in *The Lone House*. He died at Plymouth on June 28, 1835. In 1797 he had married Eliza Kirkham Strong (d. 1802), and in 1803 Anne Jackson, an actress, the author of the popular and diverting *Memoirs, by Mrs. Mathews* (4 vols., 1838–39).

His son CHARLES JAMES MATHEWS (1803–1878), who was born at Liverpool on Dec. 26, 1803, was educated at Merchant Taylors' school, and then articled as pupil to an architect. On Dec. 7, 1835, he played George Rattleton in his own play *The Humpbacked Lover* at the Olympic theatre, London. In 1838 he married Madame Vestris, then lessee of the Olympic, but his management of this theatre, and subsequently of Covent Garden, and of the Lyceum, did not succeed financially. In the year of his marriage he visited America. As an actor he held in England an unrivalled place in his peculiar vein of light eccentric comedy. The easy grace of his manner, and the imperturbable solemnity with which he perpetrated his absurdities, never failed to charm and amuse, his humour being measured and restrained. He excelled in plays like *The Game of Speculation, My Awful Dad, Cool as a Cucumber, Patter versus Clatter* and *Little Toddlekins*. In 1856 Mme. Vestris died, and the next year Mathews visited the United States, where in 1858 he married Mrs. A. H. Davenport.

Mathews was one of the few English actors who played in French successfully; he appeared in Paris in 1863 in a French version of *Cool as a Cucumber,* written by himself. At the age of 65 Mathews set out on a world tour, which included a third visit to America, and on his return in 1872 he continued to act till his death on June 24, 1878. He made his last appearance in New York at Wallack's theatre on June 7, 1872, in H. J. Byron's *Not such a Fool as he Looks*. His last appearance in London was at the Opéra Comique on June 2, 1877, in *The Liar* and *The Cosy Couple*. At Stalybridge he gave his last performance on June 8, 1878, when he played Evergreen in his own comedy *My Awful Dad*.

See the *Life of Charles James Mathews,* ed. Charles Dickens (2 vols., 1879); H. G. Paine, *Actors and Actresses of Great Britain and the United States* (New York, 1886).

MATHEWS, SHAILER (1863–), American educator and theologian, was born at Portland (Me.), on May 26, 1863. He graduated from Colby college (1884), and continued his studies at Newton Theological institution and the University of Berlin. He was associate professor of rhetoric (1887–89) and professor of history and political economy (1889–94) at Colby college. In 1894 he went to the University of Chicago as associate professor, and in 1897 became professor of New Testament history and interpretation. In 1908 he was made dean of the divinity school. In 1912–16 he was president of the Federal Council of the Churches of Christ in America, and he visited Japan in 1915 as representative of that body. From 1903 to 1911 he was editor of *The World To-day;* in 1913–20, of *The Biblical World*. He has written a number of books including *The Social Teaching of Jesus* (1897); *A History of New Testament Times in Palestine* (1899, rev. ed., 1910); *The French Revolution* (1901, enl. ed. 1923); *The Spiritual Interpretation of History* (1916); and *The Faith of Modernism* (1924).

MATHEWS, THOMAS (1676–1751), British admiral, was born at Llandaff Court, Llandaff. He entered the navy about 1690 and after various appointments during the war with Spain (1718–20) commanded the "Kent" in the fleet of Sir George Byng (Lord Torrington). From 1722 to 1724 he had the command of a small squadron sent to repress the pirates of the coast of Malabar. He settled down at Llandaff until March 1741, when he was appointed to the command in the Mediterranean, and plenipotentiary to the king of Sardinia and the States of Italy. His unfortunate engagement with a Spanish squadron of line-of-battleships near Hyères in Feb. 1744 marked the lowest pitch reached in discipline and fighting by the fleet in the 18th century. The British fleet followed the enemy in light winds on Feb. 10, and became scattered. Mathews hoisted the signal to form the line, and then when night fell, to lie to. Lestock, who commanded in the rear, was at some distance from the body of the fleet, and obeyed the second order, with the result, apparently desired, that in the morning he was far away from Mathews. The enemy were within striking distance of the van and centre of the British fleet, and Mathews attacked their rear. Lestock never came into action at all. Several captains behaved very badly, and Mathews in anger bore down on the enemy out of his line, while the signal to keep the line was still flying at his mast head. The French and Spaniards got away, and were not pursued, though they were of inferior strength. The battle led to more than twenty courts-martial and a parliamentary inquiry. Lestock was brought to trial, and acquitted on the ground that he had obeyed orders. Mathews was condemned to be dismissed from the service on the ground that he had not only failed to pursue the enemy but had taken his fleet into action in a confused manner. Mathews died in London on Oct. 2, 1751.

See Beatson, *Naval and Military Memoirs,* vol. i. (1790; 2nd ed., 1804); Montagu Burrows, *Life of Hawke* (3rd ed., 1904). The charges and findings at the courts-martial on both Lestock and Mathews were published at the time.

MATILDA (1102–1167), queen of England and empress, daughter of Henry I. of England, by Matilda, his first wife. In 1109 she was betrothed to the emperor-elect, Henry V., and was sent to Germany, but the marriage was delayed till 1114. Her husband died in 1125, leaving her childless; and, since both her brothers were now dead, she was recalled to her father's court to receive formal recognition as his successor in England and Normandy. The reluctance of the Great Council of England to acknowledge a female sovereign was increased by her marriage to Geoffrey Plantagenet, the heir of Anjou and Maine (1129); nor was it removed by the birth of the future Henry II. in 1133. On Henry I.'s death England and Normandy accepted his nephew, Stephen, of Mortain and Boulogne. Matilda and her husband

made an attempt to win Normandy; but Matilda was at last persuaded by her half-brother, Earl Robert of Gloucester, to visit England and raise her standard in the west, where his influence was supreme. With the help of the Church and the barons of the west, Stephen was captured at Lincoln (1141); the empress was acclaimed lady or queen of England (she used both titles indifferently) and crowned at London. But her arrogance alienated the Londoners and the papal legate, Bishop Henry of Winchester. Routed at the siege of Winchester, she was compelled to release Stephen in exchange for Earl Robert, and her cause steadily declined. In 1148, having lost by the earl's death her principal supporter, she retired to Normandy, of which her husband had gained possession. Henceforward she left Henry to pursue the struggle with Stephen. She died on Jan. 30, 1167.

See O. Rössler, *Kaiserin Mathilde* (1897); J. H. Round, *Geoffrey de Mandeville* (1892).

MATILDA (1046–1115), countess or margravine of Tuscany, popularly known as the Great Countess, was descended from a noble Lombard family. Her great-grandfather, Athone of Canossa, had been made count of Modena and Reggio by the emperor Otto I., and her grandfather had, in addition, acquired Mantua, Ferrara and Brescia. Her own father, Boniface II., the Pious, secured Tuscany, the duchy of Spoleto, the county of Parma, and probably that of Cremona; and was loyal to the emperor until Henry plotted against him. Through the murder of Count Boniface in 1052 and the death of her older brother and sister three years later, Matilda was left, at the age of nine, sole heiress to the richest estate in Italy. She received an excellent education under the care of her mother, Beatrice of Bar, the daughter of Frederick of Lorraine and aunt of Henry III., who, after a brief detention in Germany by the emperor, married Godfrey IV. of Lorraine, brother of Pope Stephen IX. (1057–58). Thenceforth Matilda's lot was cast against the emperor in the great struggle over investiture, and for over 30 years she maintained the cause of the successive pontiffs, Gregory VII., Victor III., Urban II, Paschal II., with varying fortune, but with undaunted resolution. She aided the pope against the Normans in 1074, and in 1075 attended the synod at which Guibert was condemned and deprived of the archbishopric of Ravenna. Her hereditary fief of Canossa was the scene (Jan. 28, 1077) of the celebrated penance of Henry IV. before Gregory VII. She provided an asylum for Henry's second wife, Praxides, and urged his son Conrad to revolt against his father. In the course of the struggle her lands were plundered, and Pisa and Lucca lost, but she remained steadfast, and, before her death, had, by means of a league of Lombard cities, recovered all her possessions.

The donation of her estates to the Holy See, originally made in 1077 and renewed on Nov. 17, 1102, though never fully consummated on account of imperial opposition, constituted the greater part of the temporal dominion of the papacy. Matilda was twice married, first to Godfrey V. of Lorraine, surnamed the Humpbacked, who was the son of her step-father and was murdered on Feb. 26, 1076; and secondly to the 17-year-old Welf V. of Bavaria, from whom she finally separated in 1095—both marriages of policy, which counted for little in her life. Matilda was an eager student: she spoke Italian, French and German fluently, and wrote many Latin letters; she collected a considerable library; she supervised an edition of the Pandects of Justinian; and Anselm of Canterbury sent her his *Meditations*. She died at Bodeno, near Modena, on July 24, 1115, and was buried in the Benedictine church at Polirone, whence her remains were taken to Rome by order of Urban VIII. in 1635 and interred in St. Peter's.

(C. H. H.)

The contemporary record of Matilda's life in rude Latin verse, by her chaplain Domnizone (Donizo or Domenico), is preserved in the Vatican library. The best edition is that of Bethmann in the *Monumenta germ. hist. scriptores*, xii. 348–409. The text, with an Italian translation, was published by F. Davoli under the title *Vita della granda contessa Matilda di Canossa* (Règgio nell' Emilia, 1888 *seq.*).

See A. Overmann, *Gräfin Mathilde von Tuscien; ihre Besitzungen . . . u. ihre Regesten* (Innsbruck, 1895); A. Colombo, *Una Nuova vita della contessa Matilda in R. accad. d. sci., Atti*, vol. 39 (Turin, 1904); L. Tosti, *La Contessa Matilda ed i romani pontefici* (Florence, 1859); A. Pannenborg, *Studien zur Geschichte der Herzogin Matilde von Canossa* (Göttingen, 1872); F. M. Fiorentini, *Memorie della Matilda* (Lucca, 1756); E. Huddy, *Matilda Countess of Tuscany* (1900); Nora Duff, *Matilda of Tuscany* (1910); Alercati, *Nell' 8° Centenario di Matilde di Canossa. Scritti varii* (1915).

MATINS, a word now only used in an ecclesiastical sense for one of the canonical hours in the Roman Breviary, originally intended to be said at midnight, but sometimes said at dawn In the modern Roman Catholic Church, outside monastic services, the office is usually said on the preceding afternoon or evening In the Church of England the term matins is sometimes used for the order of public morning prayer.

MATISSE, HENRI (1869–), French painter, was born at Cateau (Nord) on Dec. 31, 1869. He studied at the École des Beaux-Arts, and under Gustave Moreau. He soon showed revolutionary tendencies, and was recognised as the boldest member of the group known as "les fauves." Though a painter of light, he did not treat it as the impressionists had done, by means of the juxtaposition of minute touches of colour, but by employing pure tones on a large scale. In this way he produced the effect of modelling, and, by the contrast of values, was able to give the illusion of space. He was particularly successful in his use of expressive distortion. Matisse spent two years in Morocco, but most of his work was carried on in southern France, at Collioure and Nice. Later he reduced the size of his canvases, painting still life and landscapes, as well as small feminine figures and brilliantly illuminated interiors. He is entitled to be considered as the most eminent master of the contemporary French School. His drawing exhibits sometimes a nervous restrained manner. Matisse's lithographic work is also of considerable importance.

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MATLOCK, market town, urban district, western parliamentary division, Derbyshire, England, on the river Derwent, 17 m. N. of Derby on the L.M.S. railway. Pop. (1931) 10,599. The township includes the old village of Matlock, the district of Matlock Bridge, and the health resorts of Matlock Bath and Matlock Bank. The town possesses cotton, corn and paper mills, while in the vicinity there are stone-quarries and lead mines.

MATLOCK BATH, 1½ m. S. of Matlock, with a separate railway station, overlooks the gorge of the Derwent. It has three medicinal springs, temperature 68° F, which were discovered in the 17th century. Lead mining is carried on in the district and there are extensive caverns. Similarly MATLOCK BANK has become celebrated for the number and excellence of its hydropathic establishments. A tramway, worked by a single cable, over a very steep gradient, affords easy communication with Matlock Bridge.

MATOS FRAGOSO, JUAN DE (1608–1689), popular Spanish dramatist, renowned for his adroit recasting of works by Lope de Vega, as in *La Venganza en el despeño* and others.

MATRASS, a glass vessel with a round or oval body and a long narrow neck, used in chemistry, etc., as a digester or distiller. The Florence flask of commerce is frequently adapted for this purpose. The word is possibly identical with an old name "matrass" (Fr. *materas, matelas*) for the bolt or quarrel of a cross-bow. If so, some identity of shape suggests a reason for the word "bolthead" also used as a name for the vessel. Another derivation may be the Arabic *matra*, a leather bottle.

MATRIARCHY. Tales are still told of villages (always outside the ken of the narrator) where only women dwell, whose population is maintained by the admission annually of one male who is put to death when his procreative task is done. Did such exist, therein might be found that combination of female dominance, female kinship, female inheritance which (strictly speaking) alone constitutes matriarchy or the rule of the mothers. Again there are communities the bulk of whose adult male population departs periodically to engage in some seasonal industry elsewhere. There the women form a permanent element in the social and economic order, but though in a degree matripotestal, these communities are in many instances patrilineal and the authority of the males is the ultimate basis.

Distribution of Matriliny.—Matriliny, however, the custom of reckoning kinship, descent, succession and inheritance in the

female line, still survives in various parts of the world. In Australia it is associated with a simple dual system. It is found in Sumatra, in Micronesia and Melanesia, again along with the dual organization. The primitive folk in Formosa have it. India has it in Assam among the Garos, again with a dual organization, and the Khasias. On the Malabar coast are matrilineal groups, and there are Brahmans whose succession is designated by marumakathayyam—of the sister's son, a feature of the matrilineal order. The Nairs, a warrior community who once practised polyandry, are matrilineal. It still survives in Africa about Lake Nyasa, among the Ila speaking peoples of Northern Rhodesia, in Ashanti, among lower groups in Dahomey, on the Gold and Ivory Coasts. The Iroquois in North America were matrilineal, and in their polity women played an important part—in the selection and dismissal of chiefs. It is found among many Indian tribes. (*See* L. Morgan, *Ancient Society.*)

Locality.—Sometimes the group is matrilineal but patrilocal, as in Africa where the wives settle in their husbands' villages. Elsewhere, as among the Khasias, the group is matrilineal and matrilocal, the husband living in his wife's village. That the locality of marriage affects the social order profoundly, needs no elaborate proof. In those cases where marriage is matrilocal and kinship is matrilineal, the wife's kin form a definite local group, ready and able to exert supreme authority in cases of conflict, but the husband, the father, has a meed of respect in the family and in his wife's community. Every social system contains both the seeds of conflict, and devices for dealing with them as and when they may arise. In matrilineal societies where patrilocality prevails, the women as in Africa have evolved organizations on the basis of sex solidarity—secret societies (*q.v.*).

Survivals.—Many customs have been interpreted as survivals of a former matrilineal order, such as the important social functions discharged by the maternal uncle in initiation rites, at birth, marriage and death (*see* AVUNCULATE). Some at least are compatible with a patrilineal system in which cross-cousin marriage was appreciated for its economic and social advantages. Here and there women are selected as priestesses, ministrants to divine beings, sometimes by reason of the demand of a male deity for a female servant—more often, by reason of the special psychological characteristics of her sex. But that may and does happen, consistently enough, in sternly patripotestal communities.

Social Theories.—From the time of Bachofen whose work on Mutterrecht was the first scientific attack on the problem, students of social theory have been tempted to see in the matrilineal system, the primitive form of society because "paternity was a matter of inference as opposed to maternity which is a matter of observation" (Maine, *Early Law and Custom*). They pointed to cases of polyandry where paternity was uncertain but laid stress on the patrilineal order of the Tibetans and Todas where paternal polyandry prevails. Ideas such as these survive, revive, die down only to reappear, sometimes reinforced by a parade of biological, psychological and sentimental argument adorned by a wealth of illustration garnered from China to Peru, which ignores the verdict of modern anthropological research that "in all parts of the world we find maternal kinship side by side with institutions of paternal authority," and "in all the matters in which the father and the mother are vitally essential to the child, kinship has to be counted on both sides." (Malinowski, *Sex and Repression in Savage Society.*) The family is a continuous instrument essential for the transmission of culture, and human society as we now know it, and as the earliest records of humanity portray it, is a cultural phenomenon, and the family is always a bilateral unit. It is true that everywhere descent, succession and inheritance are determined unilaterally, either by matrilineal or patrilineal reckoning, but it is also true that some of the elements which compose status in the most marked matrilineal society are due to paternality. Speculation may lay stress on the assumed priority of matriliny, though the unilinear theory of social evolution has long been discarded. So keen a mind as that of Maine never imagined that "any amount of evidence of law or usage, written or observed, would by itself solve the problems which cluster round the beginnings of human society," and Darwin, leader of a host of profound biological thinkers, declared firmly for the conclusion proffered by the latest expert critic that "the hypothesis according to which promiscuity has formed a general stage in the social history of mankind is one of the most unscientific ever set forth within the whole domain of sociological speculation." (Westermarck, *History of Human Marriage,* 5th ed.) From promiscuity through matriarchy to patriarchy was the scheme proposed. The family (the bilateral unit) exists always, everywhere, and motherhood and fatherhood are nowhere independent, exempt from the pressure of reciprocity, the primeval principle of social organization.

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MATRIMONY, a game at cards played with a full whist pack upon a table divided into three compartments labelled "Matrimony," "Intrigue" and "Confederacy," and two smaller spaces, "Pair" and "Best." These names indicate combinations of two cards, any king and queen being "Matrimony," any queen and knave "Intrigue," any king and knave "Confederacy"; while any two cards of the same value are a "Pair" and the diamond ace is "Best." The dealer distributes a number of counters, on the compartments, and the other players do likewise. He then gives one card to each player, face down, and a second, face up. If any turned-up card is the diamond ace, the player holding it takes everything on the space and the deal passes. If not turned, the diamond ace has only the value of the other three aces. If it is not turned, the players, beginning with the eldest hand, expose their second cards, and the resulting combinations, if among the five successful ones, win the counters of the corresponding spaces. If the counters on a space are not won, they remain until the next deal.

MATRIX, a word derived from the Latin for womb, chiefly used in the sense of a bed or enclosing mass in which something is shaped or formed. Matrix is thus used of a mould in which a design or pattern is made in intaglio, and from which an impression in relief is taken (*see* SEALS). In mineralogy, the matrix is the mass in which a crystal mineral or fossil is embedded. In mathematics, it is an arrangement of numbers or symbols in a rectangular or square figure. (*See* ALGEBRAIC FORMS.)

In mediaeval Latin *matrix* and the diminutive *matricula* signified a roll or register, particularly one containing the names of the members of an institution, as of the clergy of a cathedral. From this use is derived "matriculation," the admission to membership of a university, also the name of the examination for such admission. *Matricula* was also the name of the contributions in men and money made by the various States of the Holy Roman empire, and in the recent German empire the contributions made by the federal States to the imperial finances were called *Matrikularbeiträge,* matricular contributions. (*See* GERMANY: *Finance.*)

MATSUDAIRA, TSUNEO (1877–), Japanese diplomat, was born in Tōkyō. He studied at the Imperial University of Tōkyō, and in 1902 entered the Foreign Office. His first experience abroad was gained in Peking where he was a secretary of legation. He became first secretary of the embassy in London, and later in Paris. From 1918–9 he was Japanese high commissioner in Siberia and in 1920 was appointed director of the bureau for European and American affairs at the Foreign Office in Tōkyō. In 1921–2 Matsudaira was chief secretary of the Japanese delegation to the Washington Conference. In 1923, he held the appointment of vice-minister for foreign affairs. In 1925, after criticism of Hanihara, the Japanese ambassador, Matsudaira was appointed ambassador and he undertook his duties with the avowed intention of bettering American-Japanese relations. He returned from Washington in the summer of 1928, and was appointed ambassador to London. His eldest daughter Setsuko was married to Prince Chichibu, brother of the Emperor of Japan, on Sept. 28, 1928.

MATSUKATA, MASAYOSHI, PRINCE MARQUIS (1835–1924), Japanese statesman, was born at Kagoshima in 1835, being a son of a *samurai* of the Satsuma clan. On the completion of the feudal revolution of 1868 he was appointed governor of the province of Tosa, and in 1874 was transferred to Tōkyō as assistant

minister of finance. In 1880 he held the portfolio of home affairs, and in 1881 was minister of finance. The condition of the currency of Japan was at that time deplorable, and national bankruptcy threatened. The coinage had not only been seriously debased, but much paper currency had been circulated as a temporary expedient for filling an impoverished exchequer. In 1878 depreciation had set in, and the inconvertible paper had by the close of 1881 grown to such an extent that it was then at a discount of 80% as compared with silver. Matsukata urged that the issue of further paper currency should be stopped at once, the expenses of administration curtailed, and the resulting surplus of revenue used in the redemption of the paper currency and in the creation of a specie reserve. These proposals were acted upon: the Bank of Japan was established, with the right of issuing convertible notes; within three years the paper currency was at par value with silver, and the currency placed on a solvent basis.

From this time Japan's commercial and military advancement made uninterrupted progress. But *pari passu* with the impetus given to trade by the successful conclusion of the war with China, the national expenditure rose within a few years from 80 to 250 million yen. The task of providing for this expenditure fell on Matsukata, who had to face the diet's opposition. But he distributed the increased taxation so equally, and chose its subjects so wisely, that the ordinary administrative expenditure and the interest on the national debt were fully provided for, while the unusual military expenditure was met from the Chinese indemnity. In 1878 Matsukata saw the advantages of a gold standard, but not until 1897 when the bill authorizing it was passed, could his scheme be realized.

Matsukata, who in 1884 was created count, twice held the office of prime minister (1891–92, 1896–98), and during both his administrations he combined the portfolio of finance with the premiership; from Oct. 1898 to Oct. 1900 he was minister of finance only. His name in Japanese history is indissolubly connected with the financial progress of his country at the end of the 19th century. In September 1907 he was advanced to the rank of marquis. From 1917 to 1922 he was keeper of the privy seal, and on resigning from this post was created a prince. He died in Tōkyō on July 2, 1924.

MATSYS (Massys or Metzys), **QUENTIN** (1466–1530), Flemish artist, was born at Louvain where he learned the trade of a blacksmith. During the greater part of the 15th century, the centres in which the painters of the Low Countries most congregated were Bruges, Ghent and Brussels. Towards the close of the same period Louvain took a prominent part in giving employment to workmen of every craft. It was not till the opening of the 16th century that Antwerp usurped the lead which it afterwards maintained against Bruges and Ghent, Brussels, Mechlin and Louvain. Quentin Matsys was one of the first men of any note who gave repute to the guild of Antwerp. A legend relates how the smith of Louvain was induced by affection for the daughter of an artist to change his trade and acquire proficiency in painting. Van Mander does not give us the name of his master. He was ten years old when Dierick Bouts died at Louvain, and his style was probably formed by the Bouts tradition, which survived in the workshop of Dierick's son, Albert. In 1491 Matsys went to Antwerp, and was there admitted into the guild of St. Luke. He was one of the first men of any note in the guild of that city, which was then rapidly becoming the most important commercial centre in the Netherlands. Early works by the master are two pictures of "The Virgin and Child" in the Brussels gallery. Matsys' most celebrated picture is the great triptych of the "Pieta," which he executed in 1511 for the joiners' company, in the cathedral of Antwerp. It is now in the Antwerp museum. Next in importance is the "Marys of Scripture round the Virgin and Child," which was ordered for the cathedral of Louvain and is now in the Brussels gallery. These pictures display great earnestness in expression, strong religious feeling, great minuteness of finish and a general absence of light or shade. As in early Flemish pictures, so in those of Matsys superfluous care is lavished on jewellery edgings and ornament. There is a tendency to accentuate individual expression. This tendency is illustrated in such pictures as "The Old Man and the Courtesan" in the Pourtales collection, Paris, and the "Market Bankers" in the Louvre, where an attempt is made to display cupidity and avarice. The "Ecce Homo" and "Mater Dolorosa" at Antwerp display serenity and dignity. Very attractive are his pictures with figures on a smaller scale, like the polyptych in Munich, the scattered parts of which have recently been fitted together; "The Virgin and Child," in the Aynard collection in Paris, and the two wings of an altarpiece representing "St. John" and "St. Agnes" standing against landscapes which stretch into the distance. These landscape backgrounds are often in the style of Patinir, who came to Antwerp in 1515, and is said to have painted backgrounds for some of Matsys' pictures. "The Crucifixion" in the Liechtenstein collection is believed to be the joint work of the two masters.

In 1517 Matsys was great as a portrait painter. He painted the portraits of Erasmus and of Peter Gillis to be sent to Sir Thomas More. The original of the Erasmus may be the picture of the Stroganoff collection, while the Gillis is in Lord Radnor's collection. It drew from Sir Thomas More a eulogy in Latin verse. Other portraits are at the museums of Chicago and Oldenburg, and in the collections of Lord Amherst and the prince of Liechtenstein. The man with a pair of eyeglasses in the Städel gallery at Frankfurt is full of vitality; he seems to be speaking. The Musée André, Paris, has an expressive profile of a man, signed and dated 1513. The artist obviously aimed at depicting the desires and emotions of the men of his day. When compared with portraits by Dürer or Holbein, Matsys' art appears subjective and personal. He came into contact with both German masters, for both in turn visited him in his house at Antwerp. Dürer's first call was made in August 1520. The two men must have had much in common, for they were both humanists. The lost original of Quentin's "St. Jerome in his Study," of which there is a copy in Vienna, owed something to Dürer's "St. Jerome," now at Lisbon. Holbein, as a young man of 27, passed through Antwerp in 1526 on his way to England, and he carried an introduction from Erasmus to Gillis, who was to send him to Matsys' house. The question as to how much Matsys was indebted to the Italian art of his time is difficult to determine. There is a picture by him from the Raczinski collection in the museum at Posen, representing the Virgin and Child playing with the lamb. These figures are obviously copied from Leonardo's famous "St. Anne, the Virgin and Child," now in the Louvre, except that the St. Anne is left out and the group is placed on a landscape background in the style of Patinir. Quentin Matsys died at Antwerp in 1530. He had two sons who were artists.

Jan Matsys (1509–1575) was at first a weak imitator of his parent. He became master in the guild of Antwerp in 1531, was banished for his heretical opinions in 1543, and stayed away until 1558. During these years he is supposed to have visited Italy or France. An early picture by him is the "Virgin kissing the Child" in the church of St. James at Antwerp, which imitates the "Madonna Enthroned" by his father, now at Berlin. A half-length "Judith," now in the museum at Boston, is of a later date and seems to recall Italian or French influences. To the same class belongs the "Lot and his Daughters" at Vienna, dated 1563.

Cornelys Matsys (1513–1579) became a master painter in 1531. There is a signed picture by him at Amsterdam, dated 1538, representing the "Prodigal Son," also a genre picture, signed and dated 1543 at Berlin. He painted landscapes in the style of his father, and he was also an engraver.

See Max Friedländer, *Van Eyck an Bruegel* (1921); Sir Martin Conway, *The Van Eycks and their followers* (1921).

MATTEAWAN, NEW YORK: *see* Beacon, New York.

MATTER: *see* Kinetic Theory of Matter; Atom; Nucleus.

MATTERHORN, one of the best-known mountains (14,782 ft.) in the Alps. It rises south-west of the village of Zermatt, and on the frontier between Switzerland (canton of the Valais) and Italy. Though on the Swiss side it appears to be an isolated obelisk, it is really but the butt end of a ridge, while the Swiss slope is not nearly as steep or difficult as the grand terraced walls of the Italian slope. It was first conquered, after a number of attempts chiefly on the Italian side, on July 14, 1865, by E. Whym-

per's party, three members of which perished with the guide by a slip on the descent. Three days later it was scaled from the Italian side by a party of men from Val Tournanche led by J. A. Carrel. Nowadays it is frequently ascended in summer, especially from Zermatt.

MATTHEW, ST. In Mark's list of the Twelve appointed by Christ (iii. 13 *seq.*), the name of Matthew is seventh, and is followed by that of Thomas. Apparently the evangelist has made some attempt to arrange the names in the order of their eminence in the early Church. His list may possibly indicate also that Matthew and Thomas were accustomed to work together; it was usual for Christian missionaries to work in pairs (Acts viii. 14, xi. 25, xiii. 2, xv. 22–39, 40, etc.), and Mark records that Christ sent out the Twelve on a mission "two by two" (vi. 7). In the corresponding list in the Third Gospel (Lk. vi. 15) Matthew's name occurs in the same position: the First Evangelist, who groups the names in pairs, gives "Thomas and Matthew" as the fourth (x. 3). A slightly different grouping is given in Luke's list of members of the primitive community in Jerusalem (Acts i. 13), "Philip and Thomas, Bartholomew and Matthew."

The First Evangelist, however, when he records from St. Mark the story of the call of Levi the tax-collector, substitutes the name "Matthew" for that of "Levi the son of Alphaeus"; he also adds "the tax-collector" to Matthew's name in his list of the Twelve (ix. 9, x. 3). According to tradition indeed it was Matthew himself who was the author of the First Gospel, but the tradition is undoubtedly a mistaken one. It probably had its origin in the fact that the evangelist made use of a collection of Christ's Sayings much valued by his community and believed to be the work of the Apostle Matthew: his identification of Matthew with Levi bears witness to the interest of his readers in that Apostle. *See* Matthew, Gospel of.

It is of course possible that the identification is a mistaken one. On the assumption that it is correct, "Matthew" (of which the probable meaning is "Jehovah's gift") would appear to be the Christian name of Levi, who had been employed as a tax-collector in the service of Herod Antipas, and whose call to be one of the immediate followers of Jesus Christ came to him as he sat at the custom house by the Lake of Galilee, presumably near Capernaum. It should be noted that Mark's story of his call resembles that of the call of Peter and Andrew and the sons of Zebedee: we should expect to find Levi somewhere in his list of the Twelve. As a tax-collector Levi would share in the distrust and contempt which these officials had earned for themselves everywhere: among the Jews the stigma of ritual uncleanness (through intercourse with Gentiles) was also attached to them.

According to Luke (v. 29) Levi afterwards made a great feast for Jesus in his house. But the evangelist is here rewriting Mark, whose statement that "he was sitting at meat in his house" does not necessarily bear the meaning put upon it by Luke; Mark may mean that Jesus was entertaining friends at his own table, inserting the incident here as another illustration of the attitude of Jesus towards "tax-collectors and sinners."

It will be seen that the New Testament affords us but scanty and uncertain information in regard to St. Matthew. Outside the New Testament the only statement of any importance in regard to the Apostle is the passage from Papias preserved by Eusebius: "So then Matthew composed the Oracles in the Hebrew language, and each one interpreted them as he could." A discussion of this statement will be found in the article Matthew, Gospel of.

Legend differs as to the scene of the Apostle's missionary labours, and as to whether he died a natural or a martyr's death. As the Evangelist Matthew is usually represented in Christian art by the "man" of Ezek. i. 10, Rev. iv. 7. (B. T. D. S.)

MATTHEW, TOBIAS or **TOBIE** (1546–1628), archbishop of York, son of Sir John Matthew of Ross, Herefordshire, was born at Bristol. He was educated at Wells, and then in succession at University college and Christ Church, Oxford. He was public orator in 1569, president of St. John's college, Oxford, in 1572, dean of Christ Church in 1576, vice-chancellor of the university in 1579, dean of Durham in 1583, bishop of Durham in 1595, and archbishop of York in 1606. In 1581 he had a controversy with the Jesuit Edmund Campion, and his arguments were published in Oxford in 1638 under the title, *Piissimi et eminentissimi viri Tobiae Matthew, archiepiscopi olim Eboracencis concio apologetica adversus Campianam.* While in the north he was active in forcing the recusants to conform to the Church of England. He died on March 29, 1628.

His son, Sir Tobias, or Tobie, Matthew (1577–1655), friend of Francis Bacon, was educated at Christ Church, and was early attached to the court, serving in the embassy at Paris. He sat in parliament for Newport, Cornwall, in 1601, and for St. Albans in 1604. Before this time he had become the intimate friend of Bacon, whom he replaced as member for St. Albans. When peace was made with Spain, on the accession of James I., he went to Italy, where he embraced Roman Catholicism. When he returned to England he was imprisoned. In 1608 he was exiled, but was permitted to return to England in 1617–19, and finally in 1621. At home he was known as the intimate friend of Gondomar, the Spanish ambassador. In 1623 he was sent to join Prince Charles, afterwards Charles I., at Madrid, and was knighted. He remained in England till 1640, when he was finally driven abroad by the parliament, which looked upon him as an agent of the pope. He died in the English college in Ghent on Oct. 13, 1655. In 1618 he published an Italian translation of Bacon's essays. The "Essay on Friendship" was written for him. His translation of *The Confessions of the Incomparable Doctor St. Augustine* involved him in controversy. His correspondence was published in London in 1660

For the father, *see* John Le Neve's *Fasti ecclesiae anglicanae* (1716), and Anthony Wood's *Athenae oxonienses.* For the son, the notice in *Athenae oxonienses,* an abridgment of his autobiographical *Historical Relation* of his own life, published by Alban Butler in 1795, and A. H. Matthew and A. Calthrop, *Life of Sir Tobie Matthew* (1907).

MATTHEW, GOSPEL OF ST. The Church for which this book was originally written appears to have been composed for the most part of Greek-speaking Jews, who, though broken completely with orthodox Judaism, still retained the Jewish viewpoint. For these Christians as for the Pharisee the end of the religious life is the attainment of "righteousness" by obedience to the Law, though the Law which they recognize is not the Mosaic code but that code as interpreted and supplemented by the teaching of Christ, here collected for them into five great discourses (v.–vii. 28, x., xiii. 1–52, xviii., xxiv.–xxv.), the Christian parallel to the five books of Moses. The interpretation of the Law is no longer in the hands of the scribes and Pharisees, "hypocrites," but in those of the Christian teachers. It is the Christian community that is the true Israel, and Christ, not during His earthly life but after His Resurrection, ordained that this should include Gentile as well as Jew, the terms of admission being no longer circumcision and obedience to the Law of Moses but baptism and obedience to the teaching of Christ. One of the writer's aims is to insist on the necessity of this obedience, since the community has been troubled by the activities of antinomian teachers (vii. 15 f., xiii. 41, xviii. 6, xxiv. 11, 12).

The Gospel is meant to serve as a manual of Apologetics as well as a book of Church Law. The evidence for the Christian Creed that Jesus is the Christ is found in the Old Testament, and the author is at pains to point out the correspondence between the events of the Gospel history and Old Testament predictions (*see* xxi. 2, xxvi. 15, xxvii. 34). Jesus of Nazareth is the Messiah of prophecy, and very soon those who have known Him only as the Son of Man (the writer seems to understand this title as properly applying to Jesus only under the conditions of His earthly life) will see Him as the Son of God coming in glory to judge the quick and the dead. The apocalyptic discourse in this gospel is more than double the length of the corresponding section in Mark; the immediacy of the Parousia is emphasized and predictions are more explicit (x. 23, xvi. 27, 28, xxiv. 29).

Sources.—(1) The gospel of St. Mark was the author's sole source of information for the main outlines of the life of Christ, and he has incorporated it almost entirely in his work. (2) About 200 verses of Matthew's non-Marcan material are also represented in Luke's gospel. In many instances the degree of resemblance between the two versions is so close that it is necessary to suppose that both are drawn from the same Greek source.

The symbol Q (*Quelle*, source) is commonly used to designate the common source (or sources) for these non-Marcan parallels in Matthew and Luke, which consist for the most part of sayings and discourses of Christ. (3) About 400 verses are peculiar to this gospel, of which about 100 represent narrative-matter. The author can only supplement Mark's account of the earthly life of Christ by the stories of the Birth and Infancy, two stories connected with St. Peter, the great teacher specially venerated by this Church (Peter walking on the water; the Temple tax), and by some details in regard to the Passion and Resurrection (the fate of Judas; the intervention of Pilate's wife; Pilate's exculpation of himself; the earthquake and resurrection of the saints; the sealing of the tomb and its sequel; the appearances to the women and to the Eleven). This material appears to be very largely legendary in character; there are some indications connecting it with the Aramaic-speaking Christians of Jerusalem. The eleven Old Testament quotations peculiar to Matthew (i. 23, ii. 6, 15, 18, 23, iv. 15, viii. 17, xii. 18, xiii. 35, xxi. 5, xxvii. 9) probably came from the same source, for while the evangelist himself appears to have used the Greek Old Testament and to have known no Hebrew these quotations are Christian translations from the Hebrew very little influenced by the LXX. version: it is moreover difficult to suppose that some of them (*see* ii. 15, 18) could ever have been in circulation as "proof texts" without the stories in which they are now found. Again, some of the sayings peculiar to this gospel suggest that they were ultimately derived from the Church of Jerusalem, which was so conservative in its attitude towards the Mosaic Law and so suspicious of Paul and the mission to the Gentiles, viz., sayings which appear to teach the eternal inviolability of the least commandment of the Law (v. 18, 19) and to restrict the Christian propaganda to the Jewish nation (vii. 6, x. 5, xv. 24). These however the evangelist accepts without misgiving and interprets in accordance with his own standpoint: in days of increasing lawlessness there is need to emphasize the sanctity of the Law, and the extension of the Gospel to the Gentiles was authorized by the Risen Christ.

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EVIDENCE

Authorship.—The internal evidence of the Gospel has shown us that the author was a Christian Hellenist, probably ignorant of Hebrew, who depended for his knowledge of the life and teaching of Christ upon tradition. Only a very intimate knowledge of his sources, however, would enable him to use them as he does, and the popularity of the book in the early Church is a witness to his ability.

But these results are in many respects curiously at variance with the traditional account of the authorship of the Gospel. According to Irenaeus, Origen and Eusebius the book was composed in Hebrew by the Apostle Matthew. Indications of the origin of this tradition are not wanting. (1) The Gospel itself bears witness to an interest on the part of the local Church in Matthew, for the editor identifies that Apostle with Levi the tax-collector (ix. 9, x. 3). (2) According to Eusebius, Papias in his "Expositions of Dominical Oracles" stated, apparently on the authority of John the Elder, that "Matthew composed the Oracles (*Logia*) in the Hebrew language, and each one interpreted them as he could." If, before the composition of the First Gospel, the most treasured Gospel record possessed by the local Church was a Greek translation of Matthew's "Oracles," Apostolic authority for the Gospel in which this work was incorporated might well be claimed at a time when the rival merits of various gospels began to be discussed: it could be regarded not as an improved edition of the work of Mark, who was only a follower of Apostles, but as an improved edition of an Apostolic record. It is possible indeed that the extract from Papias belongs to such a discussion of the claims of the leading Gospels. In Eusebius it is preceded by another extract from Papias which gives an account of the origin of Mark's Gospel. The tone of this is somewhat critical and suggests that the book is being compared to its disadvantage with another Gospel, presumably the Fourth. The same note of

disparagement may also be read into the second extract: "the First Gospel contains only a translation of Matthew's work. Matthew composed the Oracles in Hebrew, and the ability of translators varies."

It will be noted that in Papias' statement we have the probable origin of the tradition that the First Gospel was written in Hebrew. None, however, would have thought of connecting the statement with the First Gospel unless the tradition of its Apostolic authorship already existed.

The attempt to identify one of the sources of the First Gospel as Matthew's Logia is complicated by the obscurity of the extract from Papias. The word *logion* (oracular utterance) was frequently used in the Greek Old Testament for the "word" of the Lord, and passed into Christian use to describe "the words of the Lord Jesus" (*see* the title of Papias' own work). It is possible to take the phrase "the Logia" to mean "the Oracles of God" (*see* Rom. iii. 2) and to suppose that the Apostle's work was a collection of Old Testament "proof texts" from which the evangelist drew his peculiar Old Testament quotations (*see* above), but the existence of these quotations as a separate source apart from narrative matter is doubtful. It is more probable that the phrase should be interpreted of the "Sayings" of Christ. Apparently the evangelist made use of at least two collections of Christ's sayings, one which Luke also used (Q) and one which was marked by "particularist" tendencies. If the identification of Matthew with Levi the tax-collector is correct, it is more probable that he was the author of the former collection.

Date.—The internal evidence shows that the composition of the book must be dated after the Fall of Jerusalem in A.D. 70 (*see* xxii. 6, 7). A date after A.D. 70 must be assigned to Luke (*see* xxi. 20) and since neither evangelist used the other's work it is probable that their Gospels were composed about the same time. Details in Mark's picture of Christ and his first disciples must now be revised to be in keeping with the presuppositions of a later age. Liturgical and doctrinal formulae are beginning to crystallize (*see* xxviii. 19). The earliest certain external evidence for the existence of the First Gospel is provided by the Ignatian epistles (*c.* 110–115). These indications all point to a date between A D. 80 and 100 as the time when the book was composed.

Place of Origin.—The evangelist had access to Palestinian tradition, but apparently only limited access. His Gospel was used by Ignatius of Antioch. Both facts suggest the probability that the community for which the book was written must be looked for in Syria. It is tempting to suppose that the Gospel which concludes with the message of Christ to make disciples of the Gentiles comes from the Church of Antioch itself, the home of the Gentile mission. The veneration for Peter here displayed is an argument in favour of this supposition, for Peter was claimed by the later Church of Antioch as its first bishop. Against it must be set the fact that evidence of the influence of the teaching of St. Paul, abundant in the Ignatian epistles, is lacking in the First Gospel.

BIBLIOGRAPHY.—For general introduction *see* Burkitt, *The Gospel History and its Transmission;* Streeter, *The Four Gospels* (1924). Standard commentaries in English on the Greek text are those by Allen (1907) which is largely concerned with literary problems, Plummer (1909), which aims at supplementing Allen's work, and by McNeile (1915): there is a small commentary by B. T. D. Smith in the Cambridge Greek Testament (1927). A full bibliography will be found in Moffatt, *Introduction to the Literature of the New Testament.*

(B. T. D. S.)

MATTHEW OF PARIS (d. 1259), English monk and chronicler known to us only through his voluminous writings. He may have studied at Paris in his youth, but the earliest fact which he records of himself is his admission as a monk at St. Albans in the year 1217. His life was mainly spent in this religious house. In 1248, however, he was sent to Norway as the bearer of a message from Louis IX. of France to Haakon VI. of Norway, who invited him, a little later, to superintend the reformation of the Benedictine monastery of St. Benet Holme at Trondhjem. Apart from these missions, he pursued the study of history, following the tradition of the monks of St. Albans. Matthew edited anew the works of Abbot John de Cella and Roger of Wendover, which in their altered form constitute the first part of his most important work, the *Chronica maiora.* From 1235, where Wendover breaks off, Matthew continued the history. He derived much of his information from the letters of important personages, which he sometimes inserts, but more from conversation with the eye-witnesses of events. Among his informants were Earl Richard of Cornwall and Henry III.

In 1257, in the course of a week's visit to St. Albans, Henry kept the chronicler beside him night and day, "and guided my pen," says Paris, "with much good will and diligence." It is therefore curious that the *Chronica maiora* gives an unfavourable account of the king's policy. Luard supposes that Matthew never intended his work to see the light in its present form, and many passages of the autograph have against them the note *offendiculum,* which shows that the writer understood the danger which he ran. Unexpurgated copies were made in Matthew's lifetime; though the offending passages are omitted or softened in his abridgment of his longer work, the *Historia Anglorum* (written *c.* 1253). He was not an official historiographer.

Matthew is a vehement supporter of the monastic orders against their rivals, the secular clergy and the mendicant friars. He is violently opposed to the court and the foreign favourites. He despises the king as a statesman, though for the man he has some kindly feeling. He attacks the court of Rome for its exactions, and displays an intense nationalism. He sometimes inserts rhetorical speeches which are not only fictitious, but misleading. In other cases he tampers with the documents which he inserts (as, for instance, with the text of Magna Carta). In spite of his inexactitude, he gives a more vivid impression of his age than any other English chronicler; and it is unfortunate that his history breaks off in 1259, on the eve of the crowning struggle between Henry III. and the baronage.

BIBLIOGRAPHY.—The relation of Matthew Paris's work to those of John de Cella and Roger of Wendover may best be studied in H. R. Luard's edition of the *Chronica maiora* (7 vols., Rolls series, 1872–83), which contains valuable prefaces. The *Historia Anglorum sive historia minor* (1067–1253) has been edited by F. Madden (3 vols., Roll series, 1866–69). Matthew Paris is often confused with "Matthew of Westminster," the reputed author of the *Flores historiarum* edited by H. R. Luard (3 vols , Rolls series, 1890). This work, compiled by various hands, is an edition of Matthew Paris, with continuations extending to 1326. Matthew Paris also wrote a life of Edmund Rich (*q.v.*), which is probably the work printed in W. Wallace's *St. Edmund of Canterbury* (1893), pp. 543–588, though this is attributed by the editor to the monk Eustace; *Vitae abbatum S. Albani* (up to 1225) which have been edited by W. Watts (1640, etc.); and (possibly) the *Abbreviatio chronicorum* (1000–1255), edit. by F. Madden, in the third volume of the *Historia Anglorum.* On the value of Matthew as an historian *see* F. Liebermann in G. H. Pertz's *Scriptores* xxviii., pp. 74–106; A. Jessopp, *Studies by a Recluse* (1893); H. Plehn, *Politische Character Matheus Parisiensis* (Leipzig, 1897).

MATTHEW OF WESTMINSTER, the name of an imaginary person who was long regarded as the author of the *Flores Historiarum.* The error was first discovered in 1826 by Sir F. Palgrave, who said that Matthew was "a phantom who never existed," and later the truth of this statement was completely proved by H. R. Luard. The name appears to have been taken from that of Matthew of Paris, from whose *Chronica majora* the earlier part of the work was mainly copied, and from Westminster, the abbey in which the work was partially written.

The *Flores historiarum* is a Latin chronicle dealing with English history from the creation to 1326, although some of the earlier manuscripts end at 1306; it was compiled by various persons, and written partly at St. Albans and partly at Westminster. The part from 1306 to 1326 was written by Robert of Reading (d. 1325) and another Westminster monk. Except for parts dealing with the reign of Edward I. its value is not great. It was first printed by Matthew Parker, archbishop of Canterbury, in 1567, and the best edition is the one edited with introduction by H. R. Luard for the Rolls series (1890). It has been translated into English by C. D. Yonge (1853). *See* Luard's introduction, and C. Bémont in the *Revue critique d'histoire* (1891).

MATTHEWS, (JAMES) BRANDER (1852–1929), American essayist and dramatic critic, was born at New Orleans on Feb. 21, 1852, and educated at Columbia university (A.B., 1871; LL.B., 1873; A.M., 1874; LL.D., 1904). Though admitted to the bar he never practised but turned to writing and the study

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Mark's Gospel, to-day, contains no account of any Resurrection appearances of Christ, and it is suggested that the "lost ending" has been preserved, in part, by Matthew. Matthew's narrative however at this point suggests that his copy of Mark ended as abruptly as does our present text and that he had no detailed tradition to draw upon to complete his story.

EVIDENCE

Authorship.—The internal evidence of the Gospel has shown us that the author was a Christian Hellenist, probably ignorant of Hebrew, who depended for his knowledge of the life and teaching of Christ upon tradition. Only a very intimate knowledge of his sources, however, would enable him to use them as he does, and the popularity of the book in the early Church is a witness to his ability.

But these results are in many respects curiously at variance with the traditional account of the authorship of the Gospel. According to Irenaeus, Origen and Eusebius the book was composed in Hebrew by the Apostle Matthew. Indications of the origin of this tradition are not wanting. (1) The Gospel itself bears witness to an interest on the part of the local Church in Matthew, for the editor identifies that Apostle with Levi the tax-collector (ix. 9, x. 3). (2) According to Eusebius, Papias in his "Expositions of Dominical Oracles" stated, apparently on the authority of John the Elder, that "Matthew composed the Oracles (*Logia*) in the Hebrew language, and each one interpreted them as he could." If, before the composition of the First Gospel, the most treasured Gospel record possessed by the local Church was a Greek translation of Matthew's "Oracles," Apostolic authority for the Gospel in which this work was incorporated might well be claimed at a time when the rival merits of various gospels began to be discussed: it could be regarded not as an improved edition of the work of Mark, who was only a follower of Apostles, but as an improved edition of an Apostolic record. It is possible indeed that the extract from Papias belongs to such a discussion of the claims of the leading Gospels. In Eusebius it is preceded by another extract from Papias which gives an account of the origin of Mark's Gospel. The tone of this is somewhat critical and suggests that the book is being compared to its disadvantage with another Gospel, presumably the Fourth. The same note of

disparagement may also be read into the second extract: "the First Gospel contains only a translation of Matthew's work. Matthew composed the Oracles in Hebrew, and the ability of translators varies"

It will be noted that in Papias' statement we have the probable origin of the tradition that the First Gospel was written in Hebrew. None, however, would have thought of connecting the statement with the First Gospel unless the tradition of its Apostolic authorship already existed.

The attempt to identify one of the sources of the First Gospel as Matthew's Logia is complicated by the obscurity of the extract from Papias. The word *logion* (oracular utterance) was frequently used in the Greek Old Testament for the "word" of the Lord, and passed into Christian use to describe "the words of the Lord Jesus" (*see* the title of Papias' own work). It is possible to take the phrase "the Logia" to mean "the Oracles of God" (*see* Rom. iii. 2) and to suppose that the Apostle's work was a collection of Old Testament "proof texts" from which the evangelist drew his peculiar Old Testament quotations (*see* above), but the existence of these quotations as a separate source apart from narrative matter is doubtful. It is more probable that the phrase should be interpreted of the "Sayings" of Christ. Apparently the evangelist made use of at least two collections of Christ's sayings, one which Luke also used (Q) and one which was marked by "particularist" tendencies. If the identification of Matthew with Levi the tax-collector is correct, it is more probable that he was the author of the former collection.

Date.—The internal evidence shows that the composition of the book must be dated after the Fall of Jerusalem in A.D. 70 (*see* xxii. 6, 7). A date after A.D. 70 must be assigned to Luke (*see* xxi. 20) and since neither evangelist used the other's work it is probable that their Gospels were composed about the same time. Details in Mark's picture of Christ and his first disciples must now be revised to be in keeping with the presuppositions of a later age. Liturgical and doctrinal formulae are beginning to crystallize (*see* xxviii. 19). The earliest certain external evidence for the existence of the First Gospel is provided by the Ignatian epistles (*c.* 110–115). These indications all point to a date between A.D. 80 and 100 as the time when the book was composed.

Place of Origin.—The evangelist had access to Palestinian tradition, but apparently only limited access. His Gospel was used by Ignatius of Antioch. Both facts suggest the probability that the community for which the book was written must be looked for in Syria. It is tempting to suppose that the Gospel which concludes with the message of Christ to make disciples of the Gentiles comes from the Church of Antioch itself, the home of the Gentile mission. The veneration for Peter here displayed is an argument in favour of this supposition, for Peter was claimed by the later Church of Antioch as its first bishop. Against it must be set the fact that evidence of the influence of the teaching of St. Paul, abundant in the Ignatian epistles, is lacking in the First Gospel.

BIBLIOGRAPHY.—For general introduction *see* Burkitt, *The Gospel History and its Transmission;* Streeter, *The Four Gospels* (1924). Standard commentaries in English on the Greek text are those by Allen (1907) which is largely concerned with literary problems, Plummer (1909), which aims at supplementing Allen's work, and by McNeile (1915): there is a small commentary by B. T. D. Smith in the Cambridge Greek Testament (1927). A full bibliography will be found in Moffatt, *Introduction to the Literature of the New Testament.*

(B. T. D. S.)

MATTHEW OF PARIS (d. 1259), English monk and chronicler known to us only through his voluminous writings. He may have studied at Paris in his youth, but the earliest fact which he records of himself is his admission as a monk at St. Albans in the year 1217. His life was mainly spent in this religious house. In 1248, however, he was sent to Norway as the bearer of a message from Louis IX. of France to Haakon VI. of Norway, who invited him, a little later, to superintend the reformation of the Benedictine monastery of St. Benet Holme at Trondhjem. Apart from these missions, he pursued the study of history, following the tradition of the monks of St. Albans. Matthew edited anew the works of Abbot John de Cella and Roger of Wendover, which in their altered form constitute the first part of his most important work, the *Chronica maiora.* From 1235, where Wendover breaks off, Matthew continued the history. He derived much of his information from the letters of important personages, which he sometimes inserts, but more from conversation with the eye-witnesses of events. Among his informants were Earl Richard of Cornwall and Henry III.

In 1257, in the course of a week's visit to St. Albans, Henry kept the chronicler beside him night and day, "and guided my pen," says Paris, "with much good will and diligence." It is therefore curious that the *Chronica maiora* gives an unfavourable account of the king's policy. Luard supposes that Matthew never intended his work to see the light in its present form, and many passages of the autograph have against them the note *offendiculum,* which shows that the writer understood the danger which he ran. Unexpurgated copies were made in Matthew's lifetime; though the offending passages are omitted or softened in his abridgment of his longer work, the *Historia Anglorum* (written *c.* 1253). He was not an official historiographer.

Matthew is a vehement supporter of the monastic orders against their rivals, the secular clergy and the mendicant friars. He is violently opposed to the court and the foreign favourites. He despises the king as a statesman, though for the man he has some kindly feeling. He attacks the court of Rome for its exactions, and displays an intense nationalism. He sometimes inserts rhetorical speeches which are not only fictitious, but misleading. In other cases he tampers with the documents which he inserts (as, for instance, with the text of Magna Carta). In spite of his inexactitude, he gives a more vivid impression of his age than any other English chronicler; and it is unfortunate that his history breaks off in 1259, on the eve of the crowning struggle between Henry III. and the baronage.

BIBLIOGRAPHY.—The relation of Matthew Paris's work to those of John de Cella and Roger of Wendover may best be studied in H. R. Luard's edition of the *Chronica maiora* (7 vols., Rolls series, 1872–83), which contains valuable prefaces. The *Historia Anglorum sive historia minor* (1067–1253) has been edited by F. Madden (3 vols., Roll series, 1866–69). Matthew Paris is often confused with "Matthew of Westminster," the reputed author of the *Flores historiarum* edited by H. R. Luard (3 vols , Rolls series, 1890). This work, compiled by various hands, is an edition of Matthew Paris, with continuations extending to 1326. Matthew Paris also wrote a life of Edmund Rich (*q.v.*), which is probably the work printed in W. Wallace's *St. Edmund of Canterbury* (1893), pp. 543–588, though this is attributed by the editor to the monk Eustace; *Vitae abbatum S. Albani* (up to 1225) which have been edited by W. Watts (1640, etc); and (possibly) the *Abbreviatio chronicorum* (1000–1255), edit. by F. Madden, in the third volume of the *Historia Anglorum.* On the value of Matthew as an historian *see* F. Liebermann in G. H. Pertz's *Scriptores* xxviii., pp. 74–106; A. Jessopp, *Studies by a Recluse* (1893); H. Plehn, *Politische Character Matheus Parisiensis* (Leipzig, 1897).

MATTHEW OF WESTMINSTER, the name of an imaginary person who was long regarded as the author of the *Flores Historiarum.* The error was first discovered in 1826 by Sir F. Palgrave, who said that Matthew was "a phantom who never existed," and later the truth of this statement was completely proved by H. R. Luard. The name appears to have been taken from that of Matthew of Paris, from whose *Chronica majora* the earlier part of the work was mainly copied, and from Westminster, the abbey in which the work was partially written.

The *Flores historiarum* is a Latin chronicle dealing with English history from the creation to 1326, although some of the earlier manuscripts end at 1306; it was compiled by various persons, and written partly at St. Albans and partly at Westminster. The part from 1306 to 1326 was written by Robert of Reading (d. 1325) and another Westminster monk. Except for parts dealing with the reign of Edward I. its value is not great. It was first printed by Matthew Parker, archbishop of Canterbury, in 1567, and the best edition is the one edited with introduction by H. R. Luard for the Rolls series (1890). It has been translated into English by C. D. Yonge (1853). *See* Luard's introduction, and C. Bémont in the *Revue critique d'histoire* (1891).

MATTHEWS, (JAMES) BRANDER (1852–1929), American essayist and dramatic critic, was born at New Orleans on Feb. 21, 1852, and educated at Columbia university (A.B., 1871; LL.B., 1873; A.M., 1874; LL.D., 1904). Though admitted to the bar he never practised but turned to writing and the study

Nijni-Novgorod, Kostroma, Kazan, Perm and Simbirsk. (T. W.)

MATTO GROSSO, an inland State of Brazil, bounded N. by Amazonas and Pará, E. by Goyaz, Minas Geraes, São Paulo and Paraná, S. by Paraguay and S.W. and W. by Bolivia. It ranks next to Amazonas in size, its area, which is largely unsettled and unexplored, being 570,138 sq m., and its population (containing many Indians) est. 349,857 in 1930. The greater part of the State belongs to the western extension of the Brazilian plateau, across which runs the watershed which separates the drainage basins of the Amazon and La Plata. This elevated region is known as the plateau of Matto Grosso, and its elevations so far as known rarely exceed 3,000 feet. The northern slope of this great plateau is drained by the Araguaya-Tocantins, Xingú, Tapajos, and Guaporé-Mamoré-Madeira, all of which except the first, empty into the Amazon; the southern slope drains through a multitude of streams flowing into the Paraná and Paraguay. The general elevation in the south part of the State is much lower, and large areas bordering the Paraguay are swampy plains.

The lowland elevations in this part of the State range from 300 to 400 ft. above sea-level, the climate is hot, humid and unhealthful, and the conditions for permanent settlement are apparently unfavourable. On the highlands, however, which contain extensive open *campos,* the climate, though dry and hot, is considered healthful. The basins of the Paraná and Paraguay are separated by low mountain ranges extending north from the *sierras* of Paraguay. The resources of Matto Grosso are practically undeveloped, owing to the isolated situation of the State, the costs of transportation and the small population.

The first industry was that of mining, gold having been discovered in the river valleys on the southern slopes of the plateau, and diamonds on the head-waters of the Paraguay, about Diamantino and in two or three other districts. Gold is found chiefly in placers, and in colonial times the output was large, but the industry is now comparatively unimportant. Agriculture exists only for the supply of local needs, though tobacco of a superior quality is grown. Cattle-raising, however, has received some attention and is the principal industry of the landowners. The forests include fine woods, rubber, ipecacuanha, sarsaparilla, jaborandi, vanilla and copaiba. There is little export, however, the only means of communication until recent years being down the Paraguay and Paraná rivers by means of subsidized steamers. A railway has now been completed from São Paulo across the State to Corumbá on the Paraguay river. The capital of the State is Cuyabá, whose population in 1930 est. 41,148 (including its municipal district), and the chief commercial town is Corumbá, whose population (with the municipal district) in 1920 was 19,547, at the head of navigation for the larger river boats, and 1,986 m. from the mouth of the La Plata. Communication between these two towns is maintained by a line of smaller boats, the distance being 517 miles.

The first permanent settlements in Matto Grosso seem to have been made in 1718 and 1719, in the first year at Forquilha and in the second at or near the site of Cuyabá, where rich placer mines had been found. At this time all this inland region was considered a part of São Paulo, but in 1748 it was made a separate *capitania* and was named Matto Grosso ("great woods"). In 1752 its capital was situated on the right bank of the Guaporé river and was named Villa Bella da Santissima Trindade de Matto Grosso, but in 1820 the seat of Government was removed to Cuyabá and Villa Bella has fallen into decay. In 1822 Matto Grosso became a province of the empire and in 1889 a republican State. It was invaded by the Paraguayans in the war of 1860–65.

MATTOON, a city of Coles county, Illinois, U.S.A., in the eastern part of the State, 172 m. S. of Chicago. It is on Federal highway 45, and is served by the Big Four and the Illinois Central railways. Pop. (1920) 13,552 (97% native white); estimated locally (1928) at 16,500. It has large grain elevators and railroad repair shops, and is an important shipping point for corn, wheat, oats and broom corn. The value of its manufactures (including steam engines and water-works plants) was estimated at $6,000,000 for 1928. Mattoon was founded about 1855 and chartered as a city in 1857. It was named after an early settler.

MATURIN, CHARLES ROBERT (1782–1824), Irish novelist and dramatist, was born in Dublin in 1782, the grandson of Gabriel Jasper Maturin, Swift's successor in the deanery of St. Patrick. Charles Maturin was educated at Trinity college, Dublin, and became curate of Loughrea and then of St. Peter's, Dublin. His first novels, *The Fatal Revenge; or, the Family of Montorio* (1807), *The Wild Irish Boy* (1808) and *The Milesian Chief* (1812), issued under the pseudonym of "Dennis Jasper Murphy," were mercilessly ridiculed, but the irregular power displayed in them attracted the notice of Sir Walter Scott, who recommended the author to Byron. Through their influence Maturin's tragedy of *Bertram* was produced at Drury Lane in 1816, with Kean and Miss Kelly in the leading parts. A French version by Charles Nodier and Baron Taylor was produced in Paris at the Théâtre Favart. Two more tragedies, *Manuel* (1817) and *Fredolfo* (1819), were failures, and his poem *The Universe* (1821) fell flat. He wrote three more novels, *Women* (1818), *Melmoth, the Wanderer* (1820), and *The Albigenses* (1824). *Melmoth,* which forms its author's title to remembrance, is the best of them, and has for hero a kind of "Wandering Jew." Honoré de Balzac wrote a sequel to it under the title of *Melmoth réconcilié à l'église* (1835). Maturin died in Dublin on Oct. 30, 1824.

See N. Idman, *Charles Robert Maturin: his Life and Works* (1923).

MATVEYEV, ARTAMON SERGEYEVICH (d. 1682), Russian statesman and reformer, was one of the greatest of the precursors of Peter the Great. His parentage and the date of his birth are uncertain. In 1671 the tsar Alexius and Artamon were already on intimate terms, and on the retirement of Orduin-Nashchokin, Matveyev became the tsar's chief counsellor. Matveyev remained paramount to the end of the reign and introduced play-acting and all sorts of refining western novelties into Muscovy. The deplorable physical condition of Alexius's immediate successor Theodore III. suggested to Matveyev the elevation to the throne of the sturdy little tsarevich Peter, then in his fourth year. He purchased the allegiance of the *stryeltsi,* or musketeers, and then, summoning the boyars of the council, urged the substitution of Peter for Theodore. His arguments failed, and he was banished to Pustozersk, in northern Russia, where he remained till Theodore's death (April 27, 1682). The first *ukaz* issued in Peter's name summoned Matveyev to return to the capital and act as chief adviser to the tsaritsa Natalia. He reached Moscow on May 5, and at once proceeded to the head of the Red Staircase to meet and argue with the assembled *stryeltsi,* who had been instigated to rebel by the anti-Petrine faction. They seized and flung Matveyev into the square below, where he was hacked to pieces by their comrades.

See R. Nisbet Bain, *The First Romanovs* (London, 1905); M. P. Pogodin, *The First Seventeen Years of the Life of Peter the Great* (Rus.) (Moscow, 1875); S. M. Solovev, *History of Russia* (Rus.) (vols. 12, 13) (St. Petersburg, 1895, etc.); L. Shchepotev, *A. S. Matveyev as an Educational and Political Reformer* (Rus.) (St. Petersburg, 1906).

MAUBEUGE, a town of northern France, in the department of Nord, situated on both banks of the Sambre, here canalized, 23½ m. by rail E. by S. of Valenciennes, and about 2 m. from the Belgian frontier. Pop. (1931) 22,816. Maubeuge (*Malbodium*) owes its origin to a double monastery for men and women founded in the 7th century by St. Aldegonde, relics of whom are preserved in the church. It subsequently belonged to the territory of Hainault. It was burnt by Louis XI., by Francis I., and by Henry II., and was finally assigned to France by the Treaty of Nijmwegen. It was fortified by Vauban. Besieged in 1793 by Prince Josias of Coburg, it was relieved by the victory of Wattignies. It was unsuccessfully besieged in 1814, but was compelled to capitulate, after a vigorous resistance, in the Hundred Days. After the war of 1870, the fortifications of Maubeuge were considerably strengthened. It was taken by the Germans in Sept. 1914 after a heavy bombardment by 11-in. howitzers, having held-out longer than any other town in northern France; and it became an important base. It was retaken by the British on Nov. 9, 1918. The town has a board of trade arbitrators, and there are important

foundries, forges and blast-furnaces, together with manufactures of machine-tools.

MAUCH CHUNK (mawk chŭnk), a borough of eastern Pennsylvania, U.S.A., the county seat of Carbon county; on the Lehigh river (west bank), Federal highway 209, and the Lehigh Coal and Navigation company canal. It is served by the Central of New Jersey and the Lehigh Valley railways. Pop. (1920) 3,666 but 3,206 in 1930. Across the river is East Mauch Chunk (pop., 1930, 3,739) and 4 m. S.E. is Lehighton (*q.v.*). Mauch Chunk is on the edge of the anthracite region, in the midst of beautiful scenery. It has an altitude of 600 ft., and on either side Mt. Pisgah and Flagstaff mountain rise 1,000 ft above the town. It is a summer resort, a supply centre and shipping point for many large collieries, and has railroad shops, silk mills and dress factories. The borough was founded in 1818 by the Lehigh Coal and Navigation company, which in 1827 built a "switch-back" railway (now used for tourist traffic) to carry the coal from the mountains to the river. In 1831 the town was opened to individual enterprise, and in 1846 it was incorporated as a borough. It was the home of Asa Packer, builder of the Lehigh Valley railroad. On Summit hill there is a burning mine which has been on fire since 1832.

MAUCHLINE (mawch'lĭn), a town in the division of Kyle, Ayrshire, Scotland. Pop. (1931), 2,484. It lies 8 m. E.S.E. of Kilmarnock and 11 m. E. by N. of Ayr by the L.M.S. railway. It is situated on a gentle slope about 1 m. from the river Ayr. Wood knicknacks and curling stones are made, freestone quarried, and fairs held. The parish church, dating from 1829, stands in the middle of the village, and on the green a monument, erected in 1830, marks the spot where five Covenanters were killed in 1685. Robert Burns lived with his brother Gilbert on the farm of Mossgiel, about a mile to the north, from 1784 to 1788. Mauchline kirkyard was the scene of the "Holy Fair"; the "Jolly Beggars" met at "Poosie Nansie's"—still, though much altered, a popular inn; near the parish church (in the poet's day an old, barn-like structure) was the Whiteford Arms inn, where on a pane of glass Burns wrote the epitaph on John Dove, the landlord; "auld Nanse Tinnock's" house nearly faces the entrance to the churchyard; the Rev. William Auld was minister of Mauchline, and "Holy Willie," whom the poet scourged in the celebrated "Prayer," was one of "Daddy Auld's" elders; behind the kirkyard stands the house of Gavin Hamilton, the lawyer and firm friend of Burns, in which the poet was married. The braes of Ballochmyle, where he met the heroine of his song, "The Lass o' Ballochmyle," lie about a mile to the south-east.

MAUDE, CYRIL (1862–), English actor, was born in London on April 24, 1862, and was educated at Charterhouse. From 1896 to 1905 he was co-manager with F. Harrison of the Haymarket Theatre, London. In 1906 he went into management on his own account, and in 1907 opened his new theatre The Playhouse, which he retained until 1915. In 1888 he married the actress Winifred Emery (1862–1924), who had made her London début as a child in 1875, and acted with Irving at the Lyceum between 1881 and 1887. Maude made frequent visits to America. His works include: *The Haymarket Theatre* (1903); *The Actor in Room 931*, and *Reminiscences* (1927).

MAUDE, SIR FREDERICK STANLEY (1864–1917), British soldier, son of Gen. Sir Frederick Maude, V.C., was born at Gibraltar on June 24, 1864. In the South African War, as brigade-major of the Guards Brigade, he took part in the advance to Pretoria. After a spell in Canada as military secretary to the governor-general, he was engaged on the organization and training of the new Territorial Force. On mobilization in Aug. 1914 he was posted to the staff of the III. Army Corps and served in France until June 1915. In Aug. he was hurried out to the Dardanelles to take command of the 13th Division. There he took part in the evacuations of Suvla and of Helles, and in 1916 his division was dispatched from Egypt to Mesopotamia to aid in the relief of Kut-al-Amara. They arrived in time to bear a share in the final desperate endeavours to save the doomed stronghold, but the effort came to naught and after the surrender of Kut, Maude and his division remained facing the Turks on the Tigris. He was advanced in Sept. to the position of army commander in Mesopotamia

Maude spent three months at Basra, ensuring that when the time came his field army should be capable of acting with vigour and decision. Then, in December, he suddenly pushed forward, and within a few weeks had driven the Turks in confusion out of their entrenched camp around Kut. He occupied Baghdad on March 11, and spent the next few months consolidating his position and preparing plans for a fresh offensive. He died at Baghdad of cholera on Nov. 18, 1917. (*See* MESOPOTAMIA, OPERATIONS IN.)

See Maj.-Gen. Sir C. E. Callwell, *Life of Sir Stanley Maude* (1920).

MAUGHAM, WILLIAM SOMERSET (1874–), English novelist and playwright, is the son of Robert Ormond Maugham. He was educated at King's School Canterbury, Heidelberg University, and St. Thomas's Hospital. He served in the Secret Service in the World War. *Ashenden* is based on this. His novels are largely concerned with the East; his other plays are all rather thrown into the shade by *Our Betters*, a brilliantly witty and shamelessly cynical piece of social satire that was one of the greatest theatrical successes since the War.

His novels are *Liza of Lambeth* (1897), *The Hero* (1901), *The Explorer* (1907), *The Moon and Sixpence* (1919), *The Trembling of a Leaf* (1921), *On a Chinese Screen* (1922), *The Painted Veil* (1925), *The Casuarina Tree* (1926) and *Ashenden*, 1928. His plays include *A Man of Honour* (1903), *Jack Straw* (1908), *The Land of Promise* (1914), *Carolina* (1916), *Caesar's Wife* (1919), *East of Suez* (1922), *Our Betters* (1923), *The Camel's Back* (1924), *The Constant Wife* and *The Letter* (1927). His *Plays* are published by Heinemann (1912–).

MAULE, a province of central Chile, bounded on the north by Talca, on the east by Argentina, on the south by Nuble and Concepción and on the west by the Pacific. Pop. (1930) was 197,468; area, before the annexation of Linares in 1928, 5,685 sq. miles. The western part of Maule is traversed from north to south by the coast range. The climate is mild and healthy. Agriculture and stock-raising are the principal occupations, and hides, cattle, wheat and wines are exported. Transport facilities are afforded by the Maule, which is navigable for shallow-draught barges, and by a branch of the Government railway from Cauquenes to Parral. The provincial capital, Linares (Pop [1930] 15,074), is centrally situated. Cauquenes, the former capital, is situated on the eastern slopes of the coast cordilleras and had a population in 1930 of 12,007. The town and port of Constitución (Pop. [1930] 8,379) is situated on the south bank of the Maule, one mile above its mouth. There is a dangerous bar at the mouth of the river, but Constitución is connected with Talca by rail and has a considerable trade.

The Maule river, from which the province takes its name, is of historic interest because it is said to have marked the southern limits of the Inca empire. It rises in the Laguna del Maule, an Andean lake near the Argentine frontier, 7,218 ft. above sea-level, and flows westward about 140 m. to the Pacific. The upper part of its drainage basin contains the volcanoes of San Pedro (11,800 ft.), the Descabezado (12,795 ft.), and others of the same group of lower elevations. The upper course and tributaries of the Maule, principally in the Provinces of Linares, are largely used for irrigation.

MAUNDY THURSDAY, the Thursday before Easter. Maundy Thursday is sometimes known as *Sheer* or *Chare* Thursday, either in allusion, it is thought, to the "shearing" of heads and beards in preparation for Easter, or more probably in the word's Middle English sense of "pure," in allusion to the ablutions of the day. The chief ceremony, as kept from the early middle ages onwards—the washing of the feet of twelve or more poor men or beggars—was in the early Church almost unknown. From the 4th century ceremonial foot-washing became yearly more common, till it was regarded as a necessary rite, to be performed by the pope, all Catholic sovereigns, prelates, priests and nobles. In England the king washed the feet of as many poor men as he was years old, and then distributed to them meat, money and clothes. At Durham Cathedral, until the 16th century, every charity-boy had a monk to wash his feet. At Peterborough Abbey, in 1530, Wolsey made "his maund in Our

Lady's Chapel, having fifty-nine poor men whose feet he washed and kissed; and after he had wiped them he gave every of the said poor men twelve pence in money, three ells of good canvas to make them shirts, a pair of new shoes, a cast of red herrings and three white herrings." Queen Elizabeth performed the ceremony, the paupers' feet, however, being first washed by the yeomen of the laundry with warm water and sweet herbs. James II. was the last English monarch to perform the rite. William III delegated the washing to his almoner, and this was usual until the middle of the 18th century. Since 1754 the foot-washing has been abandoned, and the ceremony now consists of the presentation of Maundy money, officially called Maundy Pennies. These were first coined in the reign of Charles II. The service which formerly took place in the Chapel Royal, Whitehall, is now held in Westminster Abbey. It is on Maundy Thursday that in the Church of Rome the sacred oil is blessed, and the chrism prepared according to an elaborate ritual which is given in the *Pontificale*.

MAUNOURY, MICHEL JOSEPH (1847–1923), French soldier, was born at Maintenon (Eure-et-Loir) Dec. 11, 1847. Commissioned to the artillery from the École Polytechnique in 1869, he served in the Franco-German War, and in 1883 became a professor at St. Cyr. He retired in 1912, having been military governor of Paris and a member of the Conseil Supérieur de la Guerre. On Aug. 19, 1914 he was given charge of the army improvised in Lorraine from the reserve divisions. On Aug. 24 he made a brilliant attack on the left flank of the V. German Army; and when, on Aug. 26, a new VI. Army was assembled on the Somme, the command was given to Gen. Maunoury. It was this army, which, on Sept. 4, was launched against the flank of Von Kluck's I. Army—an action which opened and exercised a decisive influence on the battle of the Marne Maunoury continued to command the VI. Army throughout the development of the Aisne line of battle and in the early phases of trench warfare. On March 15, 1915 he was severely wounded, and thereafter held no active command. From Nov. 1915 till March 1916 he was Governor of Paris. He died on March 28, 1923, and was created marshal of France posthumously.

MAUPASSANT, HENRI RENÉ ALBERT GUY DE (1850–1893), French novelist and poet, was born at the Château of Miromesnil (Seine-Inférieure) on Aug. 5, 1850. His grandfather, a landed proprietor of a good Lorraine family, bequeathed a moderate fortune to his son, a Paris stockbroker, who married Mlle. Laure Lepoitevin. Maupassant was educated at Yvetot and at the Rouen lycée. A copy of verses entitled *Le Dieu créateur*, written during his year of philosophy, has been printed. He entered the ministry of marine, and was promoted to the Cabinet de l'Instruction publique, but legend says that, in a report by his chief, Maupassant is mentioned as not reaching the standard of the department in the matter of style. He divided his time between rowing expeditions and attending literary gatherings at the house of Gustave Flaubert, who was not, as he is often alleged to be, related to Maupassant but was merely an old friend of his mother. Maupassant seldom shared in the literary conversation, and upon those who met him—Turgenev, Alphonse Daudet, Catulle Mendès, José-Maria de Hérédia and Zola—he left the impression of a simple young athlete. Even Flaubert, to whom he submitted some sketches, was not greatly struck by their talent, though he encouraged the youth to persevere.

Maupassant's first essay was a dramatic piece twice given at Étretat in 1873 before an audience which included Turgenev, Flaubert and Meilhac. In this indecorous performance, of which nothing more is heard, Maupassant played the part of a woman. During the next seven years he served a severe apprenticeship to Flaubert, and in 1880 published a volume of poems, *Des Vers*, against which legal proceedings were taken and eventually withdrawn, and Flaubert, who had himself been prosecuted for his first book, *Madame Bovary*, congratulated the poet on the similarity between their literary experiences. *Des Vers* is an interesting experiment, which shows Maupassant hesitating in his choice of a medium; but he recognized that its chief deficiency—the absence of verbal melody—was fatal. Later in the year he contributed to the *Soirées de Médan*, a collection of short stories by Zola, Huysmans and others, and in the *Boule de suif* revealed himself to his amazed collaborators and the public as an admirable writer of prose and a consummate master of the *conte*, thereby furnishing an instance, rare in literary history, of a writer beginning with a masterpiece. This success was quickly followed by *La Maison Tellier* (1881), which confirmed the first impression and vanquished even those who were repelled by the author's choice of subjects.

In *Mademoiselle Fifi* (1883) he repeated his previous triumphs as a *conteur*, and in the same year published *Une Vie*, his first work on a larger scale. In modern literature there is no finer example of cruel observation than this sad picture of an average woman undergoing the constant agony of disillusion, while the effect of extreme truthfulness which it conveys justifies its subtitle—*L'Humble vérité*. On account of certain passages the sale of the volume at railway bookstalls was forbidden in France, with the natural result of drawing attention to the book and of advertising the *Contes de la bécasse* (1883), a collection of stories as improper as they are clever. *Au soleil* (1884) a book of travels, was less read than *Clair de lune, Miss Harriet, Les Soeurs Rondoli* and *Yvette*, all published in 1883–1884 when Maupassant's powers were at their highest; and the collections of 1885, *Contes et nouvelles, Monsieur Parent*, and *Contes du jour et de la nuit*, show a falling off in style. To 1885 also belongs *Bel-ami*, the cynical history of a particularly detestable, brutal scoundrel who makes his way by means of his handsome face. Maupassant is here no less vivid in realizing his literary men, his financiers and frivolous women than in dealing with his favourite peasants, boors and servants, to whom he returned in *Toine* (1886) and in *La Petite Rogue* (1886).

About this time appeared the first symptoms of the malady which destroyed him; he wrote less, and *Le Horla* (1887) suggests that he was already subject to alarming hallucinations. Restored to some extent by a sea-voyage, recorded in *Sur l'eau* (1888), he went back to short stories in *Le Rosier de Madame Husson* (1888), a burst of Rabelaisian humour equal to anything he had ever written. His novels *Pierre et Jean* (1888), *Fort comme la mort* (1889), and *Notre coeur* (1890) are touched with a profounder sympathy than had hitherto distinguished him; and this pity for the tragedy of life is deepened in some of the tales in *Inutile beauté* (1890). With *La Vie errante* (1890), a volume of travel, Maupassant's career practically closed. *Musotte*, a theatrical piece written with M. Jacques Normand, was published in 1891. He now began to take an interest in religious problems and for a while made the *Imitation* his handbook; but by this time inherited nervous maladies, aggravated by excessive physical exercises and by the imprudent use of drugs, had undermined his constitution; his misanthropy deepened and he suffered from curious delusions. A victim of general paralysis of which *La Folie des grandeurs* was one of the symptoms, he purposed passing the winter of 1891 at Cannes, but his reason slowly gave way; in Jan. 1892 he attempted suicide, and was removed to Paris, where he died in painful circumstances on July 6, 1893. He is buried in the cemetery of Montparnasse.

Maupassant began as a follower of Flaubert and of M. Zola, but, whatever the masters may have called themselves, they both remained essentially *romantiques*. The pupil is the last of the "naturalists": he even destroyed naturalism, since he did all that can be done in that direction. He had no psychology, no theories of art, no moral or strong social prejudices, no disturbing imagination, no wealth of perplexing ideas. Undisturbed by any external influence, his marvellous vision enabled him to become a supreme observer and given his literary sense, the rest was simple. He prided himself in having no invention; he described nothing that he had not seen. It is no paradox to say that his marked limitations made him the incomparable artist that he was.

Fundamentally he finds all men alike. In every grade of life he finds the same ferocious, cunning, animal instincts at work: it is not a gay world, but he knows no other; he is possessed by the dread of growing old, of ceasing to enjoy; the horror of death haunts him like a spectre. Maupassant does not prefer good to

bad, one man to another; he never pauses to argue about the meaning of life; his one aim is to discover the hidden aspect of things, to relate what he has observed, to give an objective rendering of it, and he has seen so intensely and so serenely that he is a most exact transcriber. And his style is exceedingly simple and strong; he is content to use the humblest word if only it conveys the exact picture of the thing seen. In ten years he produced some thirty volumes. With the exception of *Pierre et Jean,* his novels, excellent as they are, scarcely represent him at his best; a few pieces found among his papers were published posthumously; *Amitié amoureuse* (1897), a correspondence dedicated to his mother, is probably unauthentic; among the prefaces he wrote, only one—an introduction to a French prose version of Swinburne's *Poems and Ballads*—is likely to interest English readers; and of over two hundred *contes* a proportion must be rejected. But enough will remain to vindicate his claim to a permanent place in literature as the most perfect master of the short story.

See F. Brunetière, *Le Roman naturaliste* (1883); L. Lemaître, *Les Contemporains* (vols. i., v., vi.); R. Doumic, *Ecrivains d'aujourd'hui* (1894); an introduction by Henry James to *The Odd Number . . .* (1891); a critical preface by the earl of Crewe to *Pierre and Jean* (1902); A. Symons, *Studies in Prose and Verse* (1904). There are many references to Maupassant in the *Journal des Goncourt,* and some correspondence with Marie Bashkirtseff was printed with *Further Memoirs* of that lady in 1901. *See* also J. Rolland, *Guy de Maupassant* (1924); E. Boyd, *Guy de Maupassant* (1926); P. Borel, *Le Destin tragique de Guy de Maupassant, d'apres des documents originaux* (1927).

MAUPEOU, RENÉ NICOLAS CHARLES AUGUSTIN (1714–1792), chancellor of France, was born on Feb. 25, 1714, being the eldest son of René Charles de Maupeou (1688–1775), who was president of the parlement of Paris from 1743 to 1757. He was his father's right hand in the conflicts between the parlement and Christophe de Beaumont, archbishop of Paris, who was supported by the court. Between 1763 and 1768, dates which cover the revision of the case of Jean Calas and the trial of the comte de Lally, Maupeou was himself president of the parlement. In 1768, through the protection of Choiseul, whose fall two years later was in large measure his work, he became chancellor in succession to his father, who had held the office for a few days only. He determined to support the royal authority against the parlements. The struggle came over the trial of the case of the duc d'Aiguillon, ex-governor of Brittany, and of La Chalotais (*q.v.*) procureur-général of the province, who had been imprisoned by the governor for accusations against his administration. When the parlements showed signs of hostility against Aiguillon, Louis XV. annulled the proceedings.

Louis replied to remonstrances from the parlement by a *lit de justice,* in which he demanded the surrender of the minutes of procedure. On Nov. 27, 1770, appeared the *Édit de règlement et de discipline,* which was promulgated by the chancellor, forbidding the union of the various branches of the parlement and correspondence with the provincial magistratures. It also made a strike on the part of the parlement punishable by confiscation of goods, and forbade further obstruction to the registration of royal decrees after the royal reply had been given to a first remonstrance. This edict the magistrates refused to register, and it was registered in a *lit de justice* held at Versailles on Dec. 7, whereupon the parlement suspended its functions. After five summonses to return to their duties, the magistrates were surprised individually on the night of Jan. 19, 1771, by musketeers, who required them to sign yes or no to a further request to return. Thirty-eight magistrates gave an affirmative answer, but on the exile of their former colleagues by *lettres de cachet* they retracted, and were also exiled. Maupeou installed the council of state to administer justice pending the establishment of six superior courts in the provinces, and of a new parlement in Paris. The *cour des aides* was next suppressed.

Voltaire praised this revolution, applauding the suppression of the old hereditary magistrature, but in general Maupeou's policy was regarded as the triumph of tyranny. The remonstrances of the princes, of the nobles, and of the minor courts, were met by exile and suppression, but by the end of 1771 the new system was established, and the Bar, which had offered a passive resistance, recommenced to plead. But the death of Louis XV. in May 1774 ruined the chancellor. The restoration of the parlements was followed by a renewal of the quarrels between the new king and the magistrature. Maupeou and Terrai were replaced by Malesherbes and Turgot. Maupeou lived in retreat until his death at Thuit on July 29, 1792, having lived to see the overthrow of the *ancien régime.* His work, in so far as it was directed towards the separation of the judicial and political functions and to the reform of the abuses attaching to a hereditary magistrature, was subsequently endorsed by the Revolution; but no justification of his violent methods or defence of his intriguing and avaricious character is possible. He aimed at securing absolute power for Louis XV., but his action was in reality a serious blow to the monarchy.

The chief authority for the administration of Maupeou is the *compte rendu* in his own justification presented by him to Louis XVI. in 1789, which included a dossier of his speeches and edicts, and is preserved in the Bibliothèque nationale. These documents, in the hands of his former secretary, C. F. Lebrun, duc de Plaisance, formed the basis of the judicial system of France as established under the consulate. (*Cf.* C. F. Lebrun, *Opinions, rapports et choix d'écrits politiques,* published posthumously in 1829.) *See* further *Maupeouana* (6 vols., 1775), which contains the pamphlets directed against him; *Journal hist. de la révolution opérée . . . par M. de Maupeou* (7 vols., 1775); the official correspondence of Mercy-Argenteau; the letters of Mme. d'Épinay; Jules Flammermont, *Le Chancelier Maupeou et les parlements* (1883); Le Griel, *Le Chancelier Maupeou et la magistrature à la fin de l'ancien régime* (1906).

MAUPERTUIS, PIERRE LOUIS MOREAU DE (1698–1759), French mathematician and astronomer, was born at St. Malo on July 17, 1698. He served in the army for five years, employing his leisure in mathematical studies. In 1736 he acted as chief of the expedition sent by Louis XV. into Lapland to measure the length of a degree of the meridian. In 1740 he went to Berlin on the invitation of the king, and took part in the battle of Mollwitz, where he was taken prisoner by the Austrians. On his release he returned to Berlin, and thence to Paris. He went back to Berlin in 1744, and was chosen president of the Royal Academy of Sciences in 1746. He originated the principle of Least Action in 1744 (Mém. de l'Acad.). Maupertuis was a man of considerable ability as a mathematician, but was involved in constant quarrels, of which his controversies with König and Voltaire during the latter part of his life furnish examples. He died in Basle on July 27, 1759.

The following are his most important works: *Sur la figure de la terre* (1738); *Discours sur la parallaxe de la lune* (1741); *Discours sur la figure des astres* (1742); *Éléments de la géographie* (1742); *Lettre sur la comète de 1742* (1742); *Astronomie nautique* (1745 and 1746); *Vénus physique* (1745); *Essai de cosmologie* (Amsterdam, 1750). His *Oeuvres* were published in 1752 at Dresden and in 1756 at Lyons.

MAURA, ANTONIO MONTANER (1853–1925), Spanish statesman, was born in Palma de Mallorca on May 2, 1853. He was educated at Valencia and Madrid where he studied law. Though his pronunciation of Spanish was at first defective, by perseverance and force of personality he became in later years a great forensic and parliamentary orator. Elected deputy for his native city in 1881, he joined the Liberal party; but his instincts were conservative and in 1901 he went over to the Conservative party of which he eventually became leader. He was a constructive statesman, and though the chaotic state of the Spanish political fabric inspired in him a desire for reform, he always regarded the constitution as sacred. In 1903 he became Prime Minister, and his zeal for reform made him many enemies among the corrupt political factions of Spain. He negotiated with France on the subject of Spanish rights in Tangier and Morocco and with Great Britain concerning the *status quo* of the seas. In 1913 he resigned the leadership of the Conservative party, but, in response to appeals from the king, he formed governments in 1918, 1919 and 1921. True to his constitutional ideals, he refused to make common cause with the Directorate of 1923 which superseded parliamentary government in Spain. Nevertheless, Maura, who favoured "revolution from above," probably came nearer to Primo de Rivera's ideas than any considerable Spanish statesman of the old school. But he deprecated the Primo de Rivera dictatorship as arising out of an army revolt and therefore un-

likely to command public confidence. He died on Dec. 13, 1925.

MAU RANIPUR, a town of British India in Jahnsi district, in the United Provinces Pop. (1931), 12,797. It contains a large community of wealthy merchants and bankers. A special variety of red cotton cloth, known as *kharua,* is manufactured and exported to all parts of India.

MAUREL, VICTOR (1848–1923), French singer, was born at Marseilles, and studied at the Paris Conservatoire. He made his début in opera at Paris in 1868, and in London in 1873, and was one of the finest operatic baritones of his day. He created the leading part in Verdi's *Otello,* and was equally fine in Wagnerian and Italian opera. He died in New York on Oct. 23, 1923.

MAUREPAS, JEAN FRÉDÉRIC PHÉLYPEAUX, COMTE DE (1701–1781), French statesman, was born on April 9, 1701, at Versailles, the son of Jérôme de Pontchartrain, secretary of state for the marine and the royal household. Maurepas succeeded to his father's charge at 14, began his functions in the royal household at 17, and in 1725 he undertook the actual administration of the navy. Although essentially light and frivolous in character, Maurepas used the best brains of France to apply science to questions of navigation and of naval construction. He was disgraced in 1749, and exiled from Paris for an epigram against Madame de Pompadour. On the accession of Louis XVI., 25 years later, he became a minister of state and Louis XVI.'s chief adviser. He gave Turgot the direction of finance, placed Lamoignon Malesherbes over the royal household and made Vergennes minister for foreign affairs. At the outset of his new career he showed his weakness by recalling to their functions, in deference to popular clamour, the members of the old parlement ousted by Maupeou, thus reconstituting the most dangerous enemy of the royal power. This step, and his intervention on behalf of the American states, helped to pave the way for the French Revolution. Jealous of his personal ascendancy over Louis XVI., he intrigued against Turgot, whose disgrace in 1776 was followed after six months of disorder by the appointment of Necker. In 1781 Maurepas deserted Necker as he had done Turgot, and he died at Versailles on Nov. 23, 1781.

Maurepas is credited with contributions to the collection of facetiae known as the *Étrennes de la Saint Jean* (2nd ed., 1742). Four volumes of *Mémoires de Maurepas* (1792) are spurious. Some of his letters were published in 1896 by the *Soc. de l'hist. de Paris.*

MAURER, GEORG LUDWIG VON (1790–1872), German statesman and historian, son of a Protestant pastor, was born at Erpolzheim, near Dürkheim, in the Rhenish Palatinate, on Nov. 2, 1790. He spent the years 1812–14 in Paris studying the ancient legal institutions of the Germans and, returning to Germany in 1814, he received an appointment under the Bavarian government, afterwards filling several important official positions. In 1826 he became professor in the university of Munich. In 1829 he returned to official life, and in 1832 became a member of the council of regency for the government of Greece during the minority of King Otto. He began the task of creating institutions adapted to the requirements of a modern civilized community, but was recalled in 1834, Greece, through his enlightened efforts, obtained a revised penal code, regular tribunals and an improved system of civil procedure. His *Griechische Volk vor und nach dem Freiheitskampfe bis zum 31 Juli 1834* (Heidelberg, 1835–36) is a useful source of information for the history of Greece at that time. After the fall of the ministry of Karl von Abel (1788–1859) in 1847, he was for a short time chief Bavarian minister. He died at Munich on May 9, 1872.

Maurer's most important contribution to history is a series of books on the early institutions of the Germans issued in the form of 12 separate monographs with the general title *Geschichte der deutschen Gemeindeverfassung* (1854–71).

See K. T. von Heigel, *Denkwürdigkeiten des bayrischen Staatsrats G. L. von Maurer* (Munich, 1903).

MAURETANIA, the ancient name of the north-western angle of the African continent, bounded towards the south by the Atlas range, and extending along the coast to the Atlantic as far as the point where that chain descends to the sea, in about 30° N. lat. (Strabo p. 825). The Gaetulians to the south of the Altas range, on the date-producing slopes towards the Sahara, seem to have owed a precarious subjection to the kings of Mauretania, as afterwards to the Roman Government. A large part of the country is of great natural fertility, and in ancient times produced large quantities of corn, while the slopes of Atlas were clothed with forests, which produced, besides other kinds of timber, the celebrated ornamental wood called *citrum* (Plin., *Hist. Nat.,* 13–96), for tables of which the Romans gave fabulous prices. For physical geography, *see* MOROCCO.

Mauretania, or Maurusia, as it was called by Greek writers, signified the land of the Mauri, or Moors (q v.). The ethnical affinities of the race are uncertain; it is probable that all the inhabitants of this northern tract of Africa were kindred races belonging to the great Berber family (*see* Tissot, *Géographie comparée de la province romaine d'Afrique,* i. 400 et seq ; also BERBERS). They first appear in history at the time of the Jugurthine war (110–06 B.C), when Mauretania was under the government of Bocchus (Sallust, *Jugurtha* 19). To this Bocchus was given, after the war, the western part of Jugurtha's kingdom of Numidia. Sixty years later, at the time of the dictator Caesar, we find two Mauretanian kingdoms, one to the west of the river Mulucha under Bogud, and the other to the east under a Bocchus Both these kings took Caesar's part in the civil wars, and had their territory enlarged by him. In 25 B C. Augustus gave the two kingdoms to Juba II. of Numidia (*see* JUBA), with the river Ampsaga as the eastern frontier. Claudius incorporated the kingdom into the Roman State as two provinces, viz , Mauretania Tingitana and Mauretania Caesariensis, the latter taking its name from the city Caesarea, which Juba had adopted as his capital. These provinces were governed until the time of Diocletian by imperial procurators, and were occasionally united for military purposes. Under and after Diocletian Mauretania Tingitana was attached administratively to the *dioikesis* of Spain, with which it was in all respects closely connected.

There were seven Roman colonies in Mauretania Tingitana and eleven in Mauretania Caesariensis; these were mostly military foundations situated on the coast, and served the purpose of securing civilization against the inroads of the natives, who were not suited for town life as in Gaul and Spain, but were under the immediate government of the procurators, retaining their own clan organization. Besides these there were many municipia or *oppida civium romanorum* (Plin. 5. 19 et seq.), but, as has been made clear by French archaeologists, Roman settlements are less frequent the farther we go west, and Mauretania Tingitana has yielded but scanty evidence of Roman civilization. On the whole, Mauretania was in a flourishing condition down to the irruption of the Vandals in A.D. 429.

In 1904 the term Mauretania was revived as an official designation by the French Government and applied to the territory north of the lower Senegal under French protection, area 347,400 sq m., pop. (1931) 348,929, (*see* SENEGAL).

To the authorities quoted under AFRICA, ROMAN, may be added here Göbel, *Die West-küste Afrikas im Alterthum.*

MAURIAC, FRANÇOIS (1885–) French novelist. Mauriac's novels are concerned with the essential problems of life. They are by no means easy or light reading. The "discovery" of Mauriac was one of the triumphs of the *Cahiers Verts,* which in the post-war world took the place once held by the earlier *Cahiers de la Quinzaine.* In *Le Baiser au lépreux* (1922) the struggle is between the claims of Christianity and of human nature; the stage is set in a remote part of the Lande, and the protagonists are the two partners in an ill-assorted marriage; *Le Fleuve du Feu* (1923) handled another aspect of unhappy marriage; *Genitrix* (1924) showed the evils of too absorbing maternal love. These three books established Mauriac's reputation as one of the first novelists of his day. In one of his later books, *Destins* (1928), the conflict between Christian duty and passion is fought by a middle-aged woman who is attracted to a young man whom she has befriended.

His other works include: *La Robe prétexte* (1914); *La Chair et le Sang* (2nd ed., 1920); *Préséances* (1921); *Le Désert de l'Amour* (1925); *Orages,* poems (1925); *Les Mains jointes,* poems (1927);

Thérèse Desqueyroux (1927); *Le Roman* (1928); *Vie de Jean Racine* (1928). *See* S. de Sacy, *L'Oeuvre de François Mauriac* (1927).

MAURIAC, a town of central France, capital of an *arrondissement* in the department of Cantal, 39 m. N.N.W. of Aurillac by rail. Pop. (1931) 2,404. Mauriac, built on the slope of a volcanic hill, has a 12th-century church. The town owes its origin to the abbey, founded during the 6th century, now used as public offices and dwellings. It is the seat of a sub-prefect. There are marble quarries in the vicinity.

MAURICE [or MAURITIUS], **ST.** (d. *c.* 286), an early Christian martyr, who, with his companions, is commemorated by the Roman Catholic Church on Sept. 22. The oldest form of his story is found in the *Passio* ascribed to Eucherius, bishop of Lyons, *c.* 450, who relates how the "Theban" legion commanded by Mauritius was sent to north Italy to reinforce the army of Maximinian. Maximinian wished to use them in persecuting the Christians, but as they themselves were of this faith, they refused, and for this, after having been twice decimated, the legion was exterminated at Octodurum (Martigny) near Geneva. Gregory of Tours (*c.* 539–593) speaks of a company of the same legion which suffered at Cologne.

The cult of St. Maurice and the Theban legion is found in Switzerland (where two places bear the name in Valais, besides St. Moritz in Grisons), along the Rhine, and in north Italy. The foundation of the abbey of St. Maurice (Agaunum) in the Valais is usually ascribed to Sigismund of Burgundy (515). Relics of the saint are preserved here and at Brieg and Turin.

The *Magdeburg Centuries,* in spite of Mauritius being the patron saint of Magdeburg, declared the whole legend fictitious; J. A. du Bordien *La Légion thébenne* (Amsterdam, 1705); J. J. Hottinger in *Helvetische Kirchengeschichte* (Zürich, 1708); and F. W. Rettberg, *Kirchengeschichte Deutschlands* (Göttingen, 1845–48) have also demonstrated its untrustworthiness, while the Bollandists, De Rivaz and Joh. Friedrich uphold it.

MAURICE (MAURICIUS FLAVIUS TIBERIUS) (*c.* 539–602), East Roman emperor from 582 to 602, was of Roman descent, but a native of Arabissus in Cappadocia. He joined the army and fought with distinction in the Persian War (578–581). At the age of forty-three he was declared Caesar by the dying emperor Tiberius II., who bestowed upon him his daughter Constantina. Maurice brought the Persian War to a successful close by the restoration of Chosroes II. to the throne (591). On the northern frontier he at first bought off the Avars, but after 595 inflicted several defeats upon them through his general Crispus. By his strict discipline he provoked to mutiny the army on the Danube. The revolt spread to the popular factions in Constantinople, and Maurice consented to abdicate. He withdrew to Chalcedon, but was put to death by his successor Phocas, after witnessing the slaughter of his five sons.

The work on military art (στρατηγικά) ascribed to him is a contemporary work of unknown authorship (ed. Scheffer, *Arriani tactica et Mauricii ars militaris,* Uppsala, 1664; *see* Max Jähns, *Gesch. d. Kriegswissensch.*, i. 152–156).

See Theophylactus Simocatta, *Vita Mauricii* (ed. de Boor, 1887); E. Gibbon, *The Decline and Fall of the Roman Empire* (ed. Bury, 1896, v. 19–21, 57); J. B. Bury, *The Later Roman Empire* (1889, ii. 83–94); G. Finlay, *History of Greece* (ed. 1877, Oxford, i. 229–306).

MAURICE (1521–1553), elector of Saxony, elder son of Henry, duke of Saxony, of the Albertine branch of the Wettin family, was born at Freiberg on March 21, 1521. In Jan. 1541 he married Agnes, daughter of Philip, landgrave of Hesse. In that year he became duke of Saxony by his father's death, and he continued Henry's work of forwarding the Reformation. Duke Henry had decreed that his lands should be divided between his two sons, but as a partition was regarded as undesirable the whole of the duchy came to his elder son. Maurice made generous provision for his brother Augustus, and the desire to compensate him still further was one of the minor threads of his subsequent policy. In 1542 he assisted the emperor Charles V. against the Turks, in 1543 against William, duke of Cleves, and in 1544 against the French. The harmonious relations between the two branches of the Wettins were disturbed by the interference of Maurice in Cleves, a proceeding distasteful to the Saxon elector, John Frederick; and a dispute over the bishopric of Meissen having widened the breach, war was only averted by the mediation of Philip of Hesse and Luther. Maurice now began to covet the electoral dignity held by John Frederick, and in June 1546 he took a decided step by making a secret agreement with Charles V. at Regensburg. Maurice was promised some rights over the archbishopric of Magdeburg and the bishopric of Halberstadt; immunity, in part at least, for his subjects from the Tridentine decrees; and the question of transferring the electoral dignity was discussed. In return the duke probably agreed at all events to remain neutral during the impending war. The struggle began in July 1546, and in October Maurice declared war against John Frederick, having secured the formal consent of Charles to the transfer of the electoral dignity. John Frederick (*q.v.*) hastened from south Germany to defend his dominions. Maurice's ally, Albert Alcibiades, prince of Bayreuth, was taken prisoner at Rochlitz; and the duke, driven from electoral Saxony, was unable to prevent his own lands from being overrun. But Charles V., aided by Maurice, gained a decisive victory over John Frederick at Mühlberg in April 1547, after which by the capitulation of Wittenberg John Frederick renounced the electoral dignity in favour of Maurice, who also obtained a large part of his kinsman's lands.

Maurice soon found causes of complaint against the emperor in the continued imprisonment of his father-in-law, Philip of Hesse, whom he had induced to surrender to Charles and whose freedom he had guaranteed; and in Charles's refusal to complete the humiliation of the family of John Frederick. While assuring Charles of his continued loyalty, the elector entered into negotiations with the discontented Protestant princes. In 1550 he had been entrusted with the execution of the imperial ban against the city of Magdeburg, and under cover of these operations he was able to collect troops and to concert measures with his allies. Favourable terms were granted to Magdeburg, which surrendered and remained in the power of Maurice, and in Jan. 1552 a treaty was concluded with Henry II. of France at Chambord. Meanwhile Maurice had refused to recognize the Augsburg *Interim* (May 1548) as binding on Saxony; but a compromise was arranged on the basis of which the Leipzig *Interim* was drawn up for his lands. Charles was unprepared for the attack made by Maurice and his allies in March 1552, though he may have suspected his loyalty. Augsburg was taken, the pass of Ehrenberg was forced, and in a few days the emperor left Innsbruck as a fugitive. Ferdinand undertook to make peace, and the Treaty of Passau, signed in Aug. 1552, was the result. Maurice obtained a general amnesty and freedom for Philip of Hesse, but was unable to obtain a perpetual religious peace for the Lutherans. Charles stubbornly insisted that this question must be referred to the diet, and Maurice was obliged to give way. He then fought against the Turks, and renewed his communications with Henry of France. Returning from Hungary the elector placed himself at the head of the princes who were seeking to check the career of his former ally, Albert Alcibiades, whose depredations were making him a curse to Germany. The rival armies met at Sievershausen on July 9, 1553, where after a fierce encounter Albert was defeated. The victor, however, was wounded during the fight and died two days later.

The elector's *Politische Korrespondenz* was edited by E. Brandenburg (Leipzig, 1900–04); and a sketch of him is given by Roger Ascham in *A Report and Discourse of the Affairs and State of Germany* (1864–65). *See* also W. Maurenbrecher in the *Allgemeine deutsche Biographie,* Bd. XXII. (Leipzig, 1885); E. Brandenburg, *Moritz von Sachsen* (Leipzig, 1898). For bibliography *see* Maurenbrecher; and *The Cambridge Modern History,* vol. ii. (Cambridge, 1903).

MAURICE, SIR FREDERICK BARTON (1871–), British soldier, the eldest son of General Sir Frederick Maurice K.C.B., was born on Feb. 1, 1871, and was commissioned in the Sherwood Foresters in 1892. He saw service in the Tirah campaign (1897–98) and in South Africa (1899–1900), and from 1904 until 1914 held a series of general staff appointments, the last year as instructor at the Staff College. On the outbreak of the World War he was appointed General Staff Officer (1st grade) to the 3rd Div., B.E.F. He became brigadier-general, general staff, in 1915 and the same year Director of Military Operations at the

War Office. Here he was, during the middle period of the War, the intimate and valued assistant of Sir William Robertson, until the latter's resignation early in 1918. After the spring disasters Maurice wrote a letter to the Press challenging the accuracy of ministerial statements, considering them an attempt to shift the responsibility on to the army when several hundred thousand troops were retained in England to guard against a hypothetical invasion. By this act of moral courage he fulfilled his sense of honesty at the sacrifice of his career. Retired for the breach of discipline he became a military correspondent. After the War he was president of the British Legion in 1932, and in 1933 became principal of East London College. He was created C.B. in 1915, and K.C M.G. in 1918.

His publications include *Forty Days in 1914* (1920); *Lord Wolseley* (with Sir George Arthur, 1924); *Robert E. Lee, the Soldier* (1925); *Governments and War* (1926).

MAURICE, JOHN FREDERICK DENISON (1805–1872), English theologian, was born at Normanston, Suffolk, on Aug. 29, 1805. He was the son of a Unitarian minister, and entered Trinity College, Cambridge, in 1823, though it was then impossible for any but members of the Established Church to obtain a degree. Together with John Sterling (with whom he founded the Apostles' Club) he migrated to Trinity Hall, whence he obtained a first class in civil law in 1827; he then came to London. He edited the *London Literary Chronicle* until 1830, and also for a short time the *Athenaeum.* He presently decided to take orders, and with this end in view entered Exeter College, Oxford. He was ordained in 1834, and after a short curacy at Bubbenhall in Warwickshire was appointed chaplain of Guy's Hospital, and became thenceforward a sensible factor in the intellectual and social life of London. In 1840 he was appointed professor of English history and literature in King's College, and to this post in 1846 was added the chair of divinity. In 1845 he was Boyle lecturer and Warburton lecturer. These chairs he held till 1853. In that year he published *Theological Essays,* and was deprived of his professorships for alleged unorthodoxy. He was at this time chaplain of Lincoln's Inn, but when he offered to resign this the benchers refused. Nor was he assailed in the incumbency of St. Peter's, Vere Street, which he held for nine years (1860–1869). During the early years of this period he was engaged in a hot and bitter controversy with H. L. Mansel (afterwards dean of St. Paul's), arising out of the latter's Bampton lecture upon reason and revelation. Maurice was a "Broad" churchman, but he often offended liberal theologians by his opposition to the Higher Criticism. His great influence arose less from his views than from the force of his personality, and the strength of his intellect, and his passionate sympathy with the oppressed.

Maurice was specially identified with two important movements for education in London. He helped to found Queen's College for the education of women (1848), and the Working Men's College (1854), of which he was the first principal. He strongly advocated the abolition of university tests (1853), and threw himself with great energy into all that affected the social life of the people. Some attempts at co-operation among working men, and the movement known as Christian Socialism, were the immediate outcome of his teaching. In 1866 Maurice was appointed professor of moral philosophy at Cambridge, and from 1870 to 1872 was incumbent of St. Edward's in that city. He died on April 1, 1872. *See* CHRISTIAN SOCIALISM.

BIBLIOGRAPHY.—His works cover nearly 40 volumes. The following are the more important works—some of them were rewritten and in a measure recast, and the date given is not necessarily that of the first appearance of the book, but of its more complete and abiding form: *Moral and Metaphysical Philosophy* (at first an article in the *Encyclopaedia Metropolitana,* 1848); *Theological Essays* (1853); *Lectures on Ecclesiastical History* (1854); *The Doctrine of Sacrifice* (1854); *The Conscience: Lectures on Casuistry* (1868); *The Lord's Prayer, a Manual* (1870). The greater part of these works were first delivered as sermons or lectures. Maurice also contributed many prefaces and introductions to the works of friends, as to Archdeacon Hare's *Charges,* Kingsley's *Saint's Tragedy,* etc.

See Sir J. Frederick Maurice, *Life of John Frederick Denison Maurice* (2 vols., 1884); B. H. Alford, *Frederick Denison Maurice* (1909) and C. F. G. Masterman, *F. D. Maurice* (1907).

MAURICE OF NASSAU, prince of Orange (1567–1625), the second son of William the Silent, by Anna, only daughter of the famous Maurice, elector of Saxony, was born at Dillenburg. At the time of his father's assassination in 1584 he was being educated at the University of Leyden, at the expense of the States of Holland and Zeeland. Despite his youth he was made stadtholder of those two provinces and president of the council of state. During the period of Leicester's governorship he remained in the background, engaged in acquiring a thorough knowledge of the military art, and in 1586 the States of Holland conferred upon him the title of prince. On the withdrawal of Leicester from the Netherlands in August 1587, Johan van Oldenbarneveldt, the advocate of Holland, became the leading statesman of the country, a position which he retained for upwards of thirty years. He had been a devoted adherent of William the Silent and he now used his influence to forward the interests of Maurice. In 1588 he was appointed by the States-General captain and admiral-general of the Union, in 1590 he was elected stadtholder of Utrecht and Overysel, and in 1591 of Gelderland.

From this time forward, Oldenbarneveldt at the head of the civil government and Maurice in command of the armed forces of the republic worked together in the task of rescuing the United Netherlands from Spanish domination (for details *see* HOLLAND). Maurice soon showed himself to be a general second in skill to none of his contemporaries. He was especially famed for his consummate knowledge of the science of sieges. The twelve years' truce on April 9, 1609 brought to an end the cordial relations between Maurice and Oldenbarneveldt. Maurice was opposed to the truce, but the advocate's policy triumphed and henceforward there was enmity between them. The theological disputes between the Remonstrants and contra-Remonstrants found them on different sides; and the theological quarrel soon became a political one. Oldenbarneveldt, supported by the States of Holland, came forward as the champion of provincial sovereignty against that of the States-General; Maurice threw the weight of his sword on the side of the union. The struggle was a short one, for the army obeyed the general who had so often led them to victory. Oldenbarneveldt perished on the scaffold, and the share which Maurice had in securing the illegal condemnation by a packed court of judges of the aged patriot must ever remain a stain upon his memory.

Maurice, who had on the death of his elder brother Philip William, in February 1618, become prince of Orange, was now supreme in the State, but during the remainder of his life he sorely missed the wise counsels of the experienced Oldenbarneveldt. War broke out again in 1621, but success had ceased to accompany him on his campaigns. His health gave way, and he died, a prematurely aged man, at the Hague on April 4, 1625. He was buried by his father's side at Delft.

BIBLIOGRAPHY.—I. Commelin, *Wilhelm en Maurits v. Nassau, pr. v. Orangien, haer leven en bedrijf* (Amsterdam, 1651); G. Groen van Prinsterer, *Archives ou correspondance de la maison d'Orange-Nassau,* 1e série, 9 vols. (Leiden, 1841–61); G. Groen van Prinsterer, *Maurice et Barneveldt* (Utrecht, 1875); J. L. Motley, *Life and Death of John of Barneveldt* (2 vols., The Hague, 1894); C. M. Kemp, v.d. *Maurits v. Nassau, prins v. Oranje in zijn leven en verdiensten* (4 vols., Rotterdam, 1843); M. O. Nutting, *The Days of Prince Maurice* (Boston and Chicago, 1894).

MAURISTS, a congregation of French Benedictines called after St. Maurus (d. 565), a disciple of St. Benedict and the legendary introducer of the Benedictine rule and life into Gaul. At the end of the 16th century the Benedictine monasteries of France had fallen into a state of disorganization and relaxation; and a reform was initiated by the abbey of St. Vanne near Verdun, which spread to other houses in Lorraine, and in 1604 the reformed congregation of St. Vanne was established. A number of French houses joined the new congregation; but as Lorraine was still independent of the French crown, it was considered desirable to form on the same lines a separate congregation for France. Thus in 1621 was established the famous French congregation of St. Maur. Most of the Benedictine monasteries of France, except those belonging to Cluny, gradually joined the new congregation, which eventually embraced nearly two hundred houses. The chief

house was Saint-Germain-des-Prés, Paris, the residence of the superior-general and centre of the literary activity of the congregation. The primary idea of the movement was not the undertaking of literary and historical work, but the return to a strict monastic régime and the faithful carrying out of Benedictine life; and throughout the most glorious period of Maurist history the literary work was not allowed to interfere with the due performance of the choral office and the other duties of the monastic life. Towards the end of the 18th century a tendency crept in, in some quarters, to relax the monastic observances in favour of study; but the constitutions of 1770 show that a strict monastic régime was maintained until the end. The course of Maurist history and work was checkered by the ecclesiastical controversies that distracted the French Church during the 17th and 18th centuries. Some of the members identified themselves with the Jansenist cause; but the bulk, including nearly all the greatest names, pursued a middle path, opposing the lax moral theology condemned in 1679 by Pope Innocent XI., and adhering to those strong views on grace and predestination associated with the Augustinian and Thomist schools of Catholic theology; and like all the theological faculties and schools on French soil, they were bound to teach the four Gallican articles. It seems that towards the end of the 18th century a rationalistic and free-thinking spirit invaded some of the houses. The congregation was suppressed and the monks scattered at the revolution, the last superior-general with forty of his monks dying on the scaffold in Paris. The present French congregation of Benedictines initiated by Dom Guéranger in 1833 is a new creation and has no continuity with the congregation of St. Maur.

The great claim of the Maurists to the gratitude and admiration of posterity is their historical and critical school, which stands quite alone in history, and produced an extraordinary number of colossal works of erudition which still are of permanent value. The foundations of this school were laid by Dom Tarisse, the first superior-general, who in 1632 issued instructions to the superiors of the monasteries to train the young monks in the habits of research and of organized work.

The full Maurist bibliography contains the names of some 220 writers and more than 700 works. The lesser works in large measure cover the same fields as those in the list, but the number of works of purely religious character, of piety, devotion and edification, is very striking. Perhaps the most wonderful phenomenon of Maurist work is that what was produced was only a portion of what was contemplated and prepared for. The French Revolution cut short many gigantic undertakings, the collected materials for which fill hundreds of manuscript volumes in the Bibliothèque nationale of Paris and other libraries of France. When one contemplates the vastness of the works in progress during any decade of the century 1680–1780; and still more, when not only the quantity but the quality of the work, and the abiding value of most of it is realized, it will be recognized that the output was prodigious and unique in the history of letters, as coming from a single society. The qualities that have made Maurist work proverbial for sound learning are its fine critical tact and its thoroughness.

The chief source of information on the Maurists and their work is Dom Tassin's *Histoire littéraire de la congregation de Saint-Maur* (1770); it has been reduced to a bare bibliography and completed by de Lama, *Bibliothèque des écrivains de la congr. de S.-M.* (1882). The two works of de Broglie, *Mabillon* (2 vols., 1888) and *Montfaucon* (2 vols., 1891), give a charming picture of the inner life of the great Maurists of the earlier generation in the midst of their work and their friends. Sketches of the lives of a few of the chief Maurists will be found in McCarthy's *Principal Writers of the Congr. of S. M.* (1868). Useful information about their literary undertakings will be found in De Lisle's *Cabinet des mss. de la Bibl. Nat. Fonds St. Germain-des-Prés*. General information will be found in the *Catholic Encyclopaedia;* Heimbucher, *Orden und Kongregationen* (1907) i. § 36; Wetzer und Welte, *Kirchenlexicon* (ed. 2) and Herzog-Hauck's *Realencyklopädie* (ed. 3), the latter an interesting appreciation by the Protestant historian Otto Zöckler of the spirit and the merits of the work of the Maurists. (E. C. B.)

MAURITANIA, a colony of French West Africa, bounded on the west by the Atlantic ocean and the Spanish Rio de Oro, on the north by the territories of South Algeria, on the east by French Sudan and on the south by Senegal. The area is 670,000 sq.km. and the population 351,625. It is a Saharan region except in the neighbourhood of the river Senegal. It comprises some mountainous massifs such as Adrar Tmar (500 metres) and Tagant (450 metres), in which are several oases, and vast plains covered by sand and dunes. The coast, 600 km. long, is indented, between Cape Blanco and Cape Mirik, by several bays, notably those of Lévrier and Arguin; to the south of Cape Mirik it is flat, straight and bordered by dunes. The population is composed of a majority of Moors, chiefly Berbers crossed with Arabs and with negroes; they are the descendants of the Zenaga, who founded, in the 11th century, the empire of the Almoravides. The chief resources are gum, the salt of the sebkhas (10 to 12,000 tons), fishing around Port-Etienne, the rearing of camels, horses, sheep, goats and asses. Internal trade is very active between Moors and negroes who furnish them with millet in exchange for dates and salt. External trade is effected by river and almost solely with Senegal. The principal towns are Port-Etienne (French fisheries, wireless station), in the Bay of Lévrier, Boghé and Kaedi. The lieutenant-governor resides at Saint Louis.

See *La Mauritanie* (publication of the General Government of West Africa, 1906); Gruvel et Bouyat, *Les pêcheries de la côte occidentale d'Afrique* (Paris, 1906); E. Richet, *La Mauritanie* (Paris, 1920), with bibl.; Gruvel et Chudeau, *A travers la Mauritanie occidentale* (Paris, 1909).

MAURITIUS, an island and British colony in the Indian ocean (known whilst a French possession as the *Île de France*). It lies between 57° 18′ and 57° 49′ E., and 19° 58′ and 20° 32′ S., 550 m. E. of Madagascar. The island is irregularly elliptical—somewhat triangular—in shape, and is 36 m. long and about 23 m. broad. It is 130 m. in circumference, and its total area is about 720 square miles. The island is surrounded by coral reefs, so that the ports are difficult of access.

Dependent upon Mauritius and forming part of the colony are a number of small islands scattered over a large extent of the Indian ocean. Of these the chief is Rodriguez (*q.v.*), 375 m. E. of Mauritius. Considerably north-east of Rodriguez is the Chagos archipelago, of which the chief is Diego Garcia (*see* CHAGOS). The Cargados, Carayos or St. Brandon islets, deeps and shoals lie at the south end of the Nazareth Bank about 250 m. N.N.E. of Mauritius.

From its mountainous character Mauritius is a most picturesque island. The most level portions of the coast districts are the north and north-east, all the rest being broken by hills, which vary from 500 to 2,700 ft. in height. The principal mountain masses are the north-western or Pouce range, in the district of Port Louis; the south-western, in the districts of the Black River and Savanne; and the south-eastern range, in the Grand Port district. In the first of these, which consists of one principal ridge with several lateral spurs, overlooking Port Louis, are the Pouce (2,650 ft.), and the Pieter Botte (2,685 ft.). The highest summit is in the south-western mass of hills, the Black River mountain (2,711 ft.). The south-eastern group of hills consists of the Montagne du Bambou, with several spurs running down to the sea. In the interior are extensive fertile plains, some 1,200 ft. in height, forming the districts of Moka, Vacois, and Plaines Wilhelms; and an abrupt peak, the Piton du Milieu de l'Île (1,932 ft.) rises from the centre of the island. Other prominent summits are the Trois Mamelles, the Montagne du Corps de Garde, the Signal Mountain, near Port Louis, and the Morne Brabant.

The rivers are small, and in the dry season little more than brooks, in the wet season, raging torrents. The principal stream is the Grande Rivière, with a course of about 10 miles. The island is of volcanic origin and the more recent craters (now extinct) cross the centre of the island. The volcanic rocks are all basic in character and belong to two periods of eruption, the earlier forming the mountain mass of the Black River district and the later being basalts and dolerites poured out from craters of the central district. Many of the craters have been partially denuded but some still contain lakes, *e.g.*, Grand Bassin, Mare aux Vacois and Mare aux Joncs. Some lava-flows alternate with coral reefs. The basement rocks are represented by a mass of clay-slates in the Black River mountains and by much contorted chlorite-schists in

La Selle mountain of the centre of the island. There is evidence of a recent elevation of from 40 ft. (south) to 12 ft. (north), whilst caves and underground rivers in the lava-flows are common.

Climate.—The climate is pleasant during the cool season of the year, but oppressively hot in summer (December to April), except in the elevated plains of the interior, where the thermometer ranges from 70° to 80°, while in Port Louis and on the coast generally it ranges from 90° to 96°. The mean temperature for the year at Port Louis is 78·6°. There are two seasons, the cool and comparatively dry season, from April to November, and the hotter season, during the rest of the year. The rainfall varies greatly in different parts of the island. Cluny in the south-east has a mean annual rainfall of 145 in.; Albion on the west is the driest station, with 31 inches. The mean monthly rainfall for the whole island varies from 12 in. in March to 2·6 in. in September and October. The Observatory and Royal Botanical Gardens are at Pamplemousses, on the dry north-west side of the island. From January to mid-April, Mauritius gets severe cyclones with torrents of rain. These hurricanes generally last about eight hours, but they appear to be less frequent and violent than in former times, owing, it is thought, to the destruction of the ancient forests and the consequent drier condition of the atmosphere. The climate is now less healthy than it was, epidemics of malarial fever having frequently occurred.

Fauna and Flora.—The present fauna is very limited in extent. When first seen by Europeans the island had no mammals except a large fruit-eating bat (*Pteropus vulgaris*), plentiful in the woods; but several mammals have been introduced. Among these are two monkeys of the genera *Macacus* and *Cercopithecus*, a stag (*Cervus hippelaphus*), a small hare, a shrew-mouse, and the ubiquitous rat. A lemur and one of the curious hedgehog-like *Insectivora* of Madagascar (*Centetes ecaudatus*) have probably both been brought from the larger island. The avifauna resembles that of Madagascar; there are species of a peculiar genus of caterpillar shrikes (*Campephagidae*), as well as of the genera *Pratincola, Hypsipetes, Phedina, Tchitrea, Zosterops, Foudia, Collocalia* and *Coracopsis*, and peculiar forms of doves and parakeets. The Dodo (*Didus ineptus*) and other flightless birds were quickly exterminated by early immigrants. Remains of large tortoises have been found. The living reptiles are small and few in number. The surrounding seas contain great numbers of fish; the coral reefs abound with a great variety of molluscs; and there are numerous land-shells.

Replacement of forests by sugar-cane has reduced the native flora. The principal timber tree is the ebony (*Diospyros ebeneum*). Besides this there are bois de cannelle, olive-tree, benzoin (*Croton Benzoe*), colophane (*Colophonia*), and iron-wood; the coco-nut palm, an importation, the palmiste (*Palma dactylifera latifolia*), the latanier (*Corypha umbraculifera*) and the date-palm. The vacoa or vacois (*Pandanus utilis*), is largely grown. In the few remnants of the original forests the traveller's tree (*Urania speciosa*), grows abundantly. A species of bamboo is very plentiful in marshy situations. A large variety of fruit is produced, including the tamarind, mango, banana, pine-apple, guava, shaddock, fig, avocado-pear, litchi, custard-apple and the mabolo (*Diospyros discolor*). Many of the roots and vegetables of Europe have been introduced, as well as some peculiar to the tropics, including maize, millet, yams, manioc, dhol, gram, etc. Small quantities of tea, rice, sago, spices (cloves, nutmeg, ginger, pepper and allspice), cotton, indigo, betel, camphor, turmeric and vanilla are grown. The Royal Botanical Gardens at Pamplemousses, which date from the French occupation of the island, contain a rich collection of tropical and extra-tropical species.

Inhabitants.—The inhabitants consist of two great divisions, European, chiefly French and British, together with numerous half-caste people, Asiatics and Africans. The population of European blood, which calls itself Creole, is greater than that of any other tropical colony; many of the inhabitants trace their descent from ancient French families, and the higher and middle classes are distinguished for their intellectual culture. French is more commonly spoken than English. The Creole class is, however, diminishing, though slowly, and the most numerous section of the population is of Indian blood.

The introduction of Indian coolies to work the sugar plantations dates from the period of the emancipation of the slaves in 1834–39. In 1846 the total population was 158,462, of these 56,245 being Indian; in 1921 the population was 376,680 including 206 in the garrison, 265,884 Indians and 6,820 Chinese. The Indio-Mauritians are now dominant in commercial, agricultural and domestic callings, and much town and agricultural land has been transferred from the Creole planters to Indians and Chinese. The tendency to an Indian peasant proprietorship is marked. Many Mauritian Creoles have emigrated to South Africa. The great increase in the population since 1851 has made Mauritius one of the most densely peopled regions of the world, having over 520 persons per square mile. (Pop. [1931] 393,238.)

Chief Towns.—The capital and seat of government, the city of Port Louis (pop. [1925] 53,708), is on the north-western side of the island, in 20° 10′ S., 57° 30′ E. at the head of an excellent harbour, a deep inlet about a mile long, available for ships of the deepest draught. This is protected by Fort William and Fort George, as well as by the citadel (Fort Adelaide), and it has three graving-docks connected with the inner harbour, the depths alongside quays and berths being from 12 to 28 feet. The trade of the island passes almost entirely through the port. The chief buildings are Government House, the Protestant cathedral, Roman Catholic cathedral, town hall, barracks, public offices, etc. Port Louis is surrounded by lofty hills and its unhealthy situation is aggravated by the difficulty of effective drainage owing to the small amount of tide in the harbour. Though much has been done to make the town sanitary, including the provision of a good water-supply, many people make their homes in the cooler uplands of the interior. Curepipe, 20 m. from Port Louis and at an altitude of 1,800 ft., is a favourite residential town. It was incorporated in 1888. On the railway between Port Louis and Curepipe are other residential towns—Beau Bassin, Rose Hill and Quatre Bornes. Mahébourg is a town on the shores of Grand Port on the south-east side of the island, Souillac a small town on the south coast.

Industries.—*The Sugar Plantations:* The soil of the island is a fertile ferruginous red clay in which stones are abundant. The greater portion of the plains is now a vast sugar plantation. The soil is suitable for the cultivation of almost all kinds of tropical produce, and increased attention is being paid to the growing of the coco-nut palm, aloes, tobacco, tea and cotton. Guano is extensively imported as a manure, and by its use the natural fertility of the soil has been increased to a wonderful extent. There is an agricultural department of the Government. The output of sugar for 1925–26 was 233,000 metric tons. The export of sugar represents over 90% of the total exports. The trade is chiefly with India, Burma, the United Kingdom and South Africa. Next to sugar, aloe-fibre is the most important export. In addition, a considerable quantity of molasses and smaller quantities of rum, copra and poonac, vanilla and coco-nut oil are exported. The imports are mainly rice, wheat, cotton goods, wine, coal, machinery, woollen goods, tobacco, hardware and haberdashery and guano. The rice comes principally from India and Madagascar; cattle are imported from Madagascar, sheep from South Africa and Australia, and frozen meat from Australia. In 1926 the imports were valued at £4,128,821 and the exports at £2,977,630. Nearly all the aloe-fibre exported is taken by Great Britain and France, while the molasses goes to India. This industry is chiefly in Chinese hands. The great majority of the imports are from Great Britain or British possessions.

The currency of Mauritius is rupees and cents of a rupee, the Indian rupee (=16d) being the standard unit. The metric system of weights and measures has been in force since 1878.

Communications.—There is a regular steamship service between Marseilles and Port Louis by the Messageries Maritimes, with Southampton via Cape Town by the Union Castle, and with Colombo direct by the British India Company's boats. There is also frequent communication with Madagascar, Réunion and Natal. The average annual tonnage of ships entering Port Louis is about 750,000, of which five-sevenths is British. Cable communication is maintained with Zanzibar, Australia, Réunion, Madagascar, Durban and so with Europe, etc.

Railways connect all the principal places and sugar estates on the island; that known as the Midland line, 36 m. long, beginning at Port Louis, crosses the island to Mahébourg, passing through Curepipe, where it is 1,822 ft. above the sea. There are in all over 144 m of railway of which 24 m. are narrow gauge, all owned and worked by the Government. The first railway was opened in 1864. The roads are well kept and there is an extensive system of tramways for bringing produce from the sugar estates to the railway lines. There is a complete telegraphic and telephonic service.

Government and Revenue.—Mauritius is a crown colony. The governor is assisted by an executive council of officials, and a Council of Government of 27 members, 8 sitting *ex officio,* 9 being nominated by the governor and 10 elected on a moderate franchise. Two of the elected members represent St. Louis, the 8 rural districts into which the island is divided electing each one member. At least one-third of the nominated members must be persons not holding any public office. The legislative session usually lasts from April to December. Members may speak either in French or in English. The (1924–25) revenue was £1,311,-523, and the expenditure was £1,157,058. Up to 1854 there was a surplus in hand, but since that time expenditure has on many occasions exceeded income, and the public debt in 1925 was £1,699,057, mainly incurred however on reproductive works.

The island has largely retained the old French laws, the *codes civil, de procédure, du commerce,* and *d'instruction criminelle* being still in force, except so far as altered by colonial ordinances. A supreme court of civil and criminal justice was established in 1831 under a chief judge and three puisne judges. Mauritius occupies an important strategic position on the route between South Africa and India and in relation to Madagascar and East Africa, while in Port Louis it possesses one of the finest harbours in the Indian Ocean. A permanent garrison is maintained in the island, and the colonial contribution to the expenditure was in 1926–27 £55,249.

Religion and Education.—The majority of the European inhabitants belong to the Roman Catholic faith. Anglicans, Roman Catholics and the Church of Scotland are helped by State grants. At the head of the Anglican community is the bishop of Mauritius; the chief Roman Catholic dignitary is styled bishop of Port Louis. There are many Mohammedans, but the majority of the Indian coolies are Hindus.

The educational system, as brought into force in 1900, is under a director of public instruction assisted by an advisory committee, and consists of two branches (1) secondary instruction, (2) primary instruction. Education is free but not compulsory. For primary instruction there are Government schools and schools maintained by the Roman Catholics, Protestants and other faiths, to which the Government gives grants in aid. Secondary and higher education is given in the Royal college and associated schools at Port Louis and Curepipe.

BIBLIOGRAPHY.—A. Macmillan, *Mauritius Illustrated* (1914); "Physical Features and Geology of Mauritius," *Q.J. Geol. Soc.* (1895); *Colonial Office List* (Annual Series); *Mauritius Almanack* (Published annually at Port Louis); *Mauritius Blue Book* (Annual, Mauritius); A. Balfour, *Reports on Medical and Sanitary Matters of Mauritius* (1922). A map (1 in. to 1 mile) was issued by the War Office in 1905.

HISTORY

Mauritius appears to have been unknown to European nations, if not to all other peoples, until the year 1505, when it was discovered by Mascarenhas, a Portuguese navigator. It had then no inhabitants, and there seem to be no traces of a previous occupation by any people. The island was retained for most of the 16th century by its discoverers, who named it "Ilha do Cerné," but they made no settlements in it. In 1598 the Dutch took possession and named the island "Mauritius," in honour of their stadtholder, Count Maurice of Nassau, but abandoned the island in 1710. From 1715 to 1767 (when the French government assumed direct control) the island was held by agents of the French East India Company, by whom its name was again changed to "Ile de France." The company was fortunate in having several able men as governors of its colony, especially the celebrated Mahé de Labourdonnais (*q.v.*), who made sugar planting the main industry of the inhabitants. Under his direction roads were made, forts built, and considerable portions of the forest were cleared, and the present capital, Port Louis, was founded. Labourdonnais also promoted the planting of cotton and indigo, and is remembered as the most enlightened and best of all the French governors. He also put down the maroons or runaway slaves who had long been the pest of the island. The colony continued to rise in value during the time it was held by the French crown, and to one of the intendants,[1] Pierre Poivre, was due the introduction of the clove, nutmeg, and other spices. Another governor was D'Entrecasteaux, whose name is kept in remembrance by a group of islands of New Guinea.

During the long war between France and England, at the commencement of the 19th century, Mauritius was a continual source of much mischief to English Indiamen and other merchant vessels; and at length the British government determined upon an expedition for its capture. This was effected in 1810; and upon the restoration of peace in 1814 the possession of the island was confirmed to Britain by the Treaty of Paris. By the eighth article of capitulation it was agreed that the inhabitants should retain their own laws, customs, and religion; and thus the island is still largely French in language, habits, and predilections; but its name has again been changed to that given by the Dutch. One of the most distinguished of the British governors was Sir Robert Farquhar (1810–23), who did much to abolish the Malagasy slave trade and to establish friendly relations with the rising power of the Hova sovereign of Madagascar.

The history of the colony since its acquisition by Great Britain has been one of social and political evolution. At first all power was concentrated in the hands of the governor, but in 1832 a legislative council was constituted on which non-official nominated members served. Under letters patent issued in 1885 and amended in 1901, 1902, and 1913, this council was transformed into a partly elected body. Of more importance than the constitutional changes were the economic results which followed the freeing of the slaves (1834–39)—for the loss of whose labour the planters received over £2,000,000 compensation. Coolies were introduced to supply the place of the negroes, immigration being definitely sanctioned by the government of India in 1842. Though under government control, the system of coolie labour led to many abuses. A royal commission investigated the matter in 1871, and since that time the evils which were attendant on the system have been gradually remedied. The last half of the 19th century was, however, chiefly notable in Mauritius for the number of calamities which overtook the island. In 1854 cholera caused the death of 17,000 persons; in 1867 over 30,000 people died of malarial fever; in 1892 a hurricane of terrific violence caused immense destruction of property and serious loss of life; in 1893 a great part of Port Louis was destroyed by fire. There were in addition several epidemics of small-pox and plague, and from about 1880 onward the continual decline in the price of sugar seriously affected the islanders, especially the Creole population. During 1902–5 an outbreak of surra, which caused great mortality among draught animals, further tried the sugar planters and necessitated government help. Notwithstanding all these calamities, the Mauritians, especially the Indo-Mauritians, have succeeded in maintaining the position of the colony as an important sugar-producing country. They have not only developed industry but have so successfully fought disease that in 1925 the death rate had fallen to non-Indian 23·8 per 1,000 and Indian 24·2.

See C. Keller, *Madagascar, Mauritius, and other East African Islands,* Eng. trans. by H. A. Nesbit (1901); De Burgh Edwardes, *The History of Mauritius* (1922).

MAUROIS, ANDRÉ (1885–), French writer, was born at Elbeuf, and educated at Rouen. He first became known to the English public by his *Silences du Colonel Bramble* (1918), based on his experiences as an interpreter during the World War. His style is delicate, but direct, and his delineation of English character has perhaps helped to make his later books also widely

[1]The régime introduced in 1767 divided the administration between a governor, primarily charged with military matters, and an intendant.

read in translation. He experiments in biography in the form of fiction, exemplified in *Ariel, ou la vie de Shelley* (1923), and this book, which had a great success, was followed by similar treatment of the life of Disraeli (1927), and of Byron (1927).

His other works include *Ni Ange ni Bête* (1919); *Les Discours du Docteur O'Grady* (1920); *Dialogues sur le Commandement* (1924); *Meïpe* (1926); *Bernard Quesnay* (1926); *Un Essai sur Dickens* (1927); *Quatre études anglaises* (1927); and *Climats* (1928).

MAURRAS, CHARLES (1868–), French writer and politician, was born at Martigues, Provence, of a royalist family. He began his journalistic career as literary critic in the *Revue Encyclopédique* and the *Gazette de France*. He then joined *L'Action Française* where he was at first the only royalist on the staff. He soon converted almost all his colleagues. After visiting Greece and Italy he published *Trois idées politiques* (1898); *Les amants de Venise* (1902); and *L'avenir de l'intelligence* (1905). This was his most productive period, during which his royalist propaganda exerted a powerful influence; he assisted Léon Daudet in transforming (1908) *L'Action Française* into a daily paper. In his *Kiel et Tanger* (1910) he criticized French foreign policy, while *Le dilemme de Marc Sangnier* (1906) dealt with religious problems. Though an avowed atheist, Maurras somewhat paradoxically favoured an alliance with the Catholic Church which he regarded as closely connected with the monarchy. Moreover, he saw in the Catholic Church an instrument for securing the political and social stability which he valued. But the strange alliance was not endorsed by the Church. *L'Action Française* lost considerable influence when the French clergy withdrew their support and defeated Daudet during his candidature for parliament in 1923 and 1925. On Oct. 29, 1926, Maurras was sentenced to two years' imprisonment and a fine of 1,000 francs for an open letter to M. Schrameck, minister of the interior, in which the minister was accused of favouring Communists; the letter might be read as an incitement to extreme violence. In 1927 consternation was created among French Catholic royalists by the promulgation of a decree (Dec. 29, 1926) placing certain of Maurras' books and *L'Action Française* itself on the index, in view of articles by Daudet and Maurras which, it was said, attacked the Holy See. This decree was accepted by the French clergy in a declaration published in Oct. 1927. In the meantime the court of appeal, while upholding the conviction of Maurras, had agreed to his release.

The articles written by Maurras during the World War appeared in eight volumes entitled *Les conditions de la victoire* (1915–20). Though the writings of Maurras produced a profound effect on French thought, his nationalist ideas failed to take deep root in his own country, but they triumphed in Italy; and *L'Idea Nazionale* with its Fascist doctrines owed much to *L'Action Française*. The French movement with which the name of Maurras is associated may be regarded as an inchoate Fascism; a minor intellectual revolution, which has not developed into any great political upheaval. Maurras himself was strongly convinced of the necessity of order in the national life, and was prepared to sacrifice much else if the discipline which he considered essential in art and morals could be enforced. Among Maurras' many works may be mentioned the following: *Jean Moréas* (1891); *Le chemin de paradis* (1894); *Anthinéa* (1901); *L'enquête sur la monarchie* (1900–09); *La politique religieuse* (1912); *Quand les Français ne s'aimaient pas* (1916); and a collection of poems *La musique intérieure* (1925).

See A. Thibaudet, *Les idées de Charles Maurras* (1920).

MAURY, JEAN SIFFREIN (1746–1817), French cardinal and archbishop of Paris, the son of a poor cobbler, was born on June 26, 1746, at Valréas in the Comtat-Venaissin. He was educated at the seminary at Avignon. In 1777 he published under the title of *Discours choisis* his panegyrics on St. Louis, St. Augustine and Fénelon, his remarks on Bossuet and his *Essai sur l'éloquence de la chaire*, a volume which contains much good criticism, and remains a French classic. The book was often reprinted as *Principes de l'éloquence*. He was Lent preacher at court in 1781, when King Louis XVI. said of his sermon: "If the abbé had only said a few words on religion he would have discussed every possible subject." In 1781 he obtained the rich priory of Lyons, near Péronne, and in 1785 he was elected to the Academy. In 1789 he was elected a member of the States General by the clergy of the bailliage of Péronne, and from the first proved to be the most able and persevering defender of the *ancien régime*, although he had drawn up the greater part of the *cahier* of the clergy of Péronne, which contained a considerable programme of reform. It is said that he attempted to emigrate both in July and in Oct. 1789; but after that time he held firmly to his place, when almost universally deserted by his friends. In the Constituent Assembly he fought against the alienation of the property of the clergy. His life was often in danger, but his ready wit always saved it, and it was said that one *bon mot* would preserve him for a month. When he did emigrate in 1792 he was at once named archbishop *in partibus*, and extra nuncio to the diet at Frankfort, and in 1794 cardinal. He was finally made bishop of Montefiascone, but in 1798 the French drove him from his retreat, and he sought refuge in Venice and St. Petersburg. Next year he returned to Rome as ambassador of the exiled Louis XVIII. In 1806 he returned to France, and in 1810 was made archbishop of Paris. He was presently ordered by the pope to surrender his functions as archbishop of Paris. This he refused to do. At the restoration he was expelled from the Academy and from the archiepiscopal palace. He retired to Rome, where he was imprisoned in the castle of St. Angelo for six months. He died in 1817, a year or two after his release, of disease contracted in prison and of chagrin.

The *Oeuvres choisies du Cardinal Maury* (5 vols., 1827) contain what is worth preserving. Mgr. Ricard has published Maury's *Correspondance diplomatique* (2 vols., Lille, 1891). For his life and character see *Vie du Cardinal Maury*, by Louis Siffrein Maury, his nephew (1828); J. J. F. Poujoulat, *Cardinal Maury, sa vie et ses oeuvres* (1855); Sainte-Beuve, *Causeries du lundi* (vol. iv.); Mgr. Ricard, *L'abbé Maury* (1746–91), *L'abbé Maury avant 1789, L'abbé Maury et Mirabeau* (1887); G. Bonet-Maury, *Le cardinal Maury d'après ses mémoires et sa correspondance inédits* (1892); A. Aulard, *Les Orateurs de la Constituante* (1882). Of the many libels written against him during the Revolution the most noteworthy are the *Petit carême de l'abbé Maury*, with a supplement called the *Seconde année* (1790), and the *Vie privée de l'abbé Maury* (1790), claimed by J. R. Hébert, but attributed by some writers to Restif de la Bretonne. For further bibliographical details *see* J. M. Quérard, *La France littéraire*, vol. v. (1833).

MAURY, MATTHEW FONTAINE (1806–1873), American naval officer and hydrographer, was born in Spottsylvania county, Virginia. He was educated at Harpeth academy, and in 1825 entered the navy as midshipman, circumnavigating the globe in the "Vincennes" during a cruise of four years (1826–30). In 1839 he met with an accident which resulted in permanent lameness, and unfitted him for active service, and in 1841 he was placed in charge of the depôt of charts and instruments, out of which grew the U.S. naval observatory and the hydrographic office. He laboured assiduously to obtain observations as to the winds and currents by distributing to captains of vessels specially prepared log-books. One result was to show the necessity for combined action on the part of maritime nations in regard to ocean meteorology. This led to an international conference at Brussels in 1853, which produced the greatest benefit to navigation as well as indirectly to meteorology. Maury's oceanographical work received recognition in all parts of the civilized world, and in 1855 he was given the rank of commander. On the outbreak of the Civil War in 1861, Maury threw in his lot with the South, and became head of coast, harbour and river defences. He invented an electric torpedo for harbour defence, and in 1862 was ordered to England to purchase torpedo material, etc. After the war he went to Mexico, and as the imperial commissioner of immigration of the emperor Maximilian, attempted to found a Virginian colony there. Incidentally he introduced there the cultivation of cinchona. The scheme of colonization was abandoned by the emperor (1866), and Maury settled for a while in England, where he was presented with a testimonial raised by public subscriptions. In 1868 a tendency toward amnesty admitting of his return to America, he accepted the professorship of meteorology in the Virginia military institute, and settled at Lexington (Va.), where he died on Feb. 1, 1873.

Among works published by Maury are the papers contributed by him to the *Astronomical Observations* of the U.S. Observatory; *Letters*

on the American and Atlantic Slopes of South America (1853); *Physical Geography of the Sea* (1855); *Letter concerning Lanes for Steamers crossing the Atlantic* (1855); *Physical Geography* (1864); *Manual of Geography* (1871).

See Diana Fontaine Maury Corbin (his daughter), *Life of Matthew Fontaine Maury* (1888) and C. L. Lewis, *Mathew Fontaine Maury, the Pathfinder of the Seas* (1927).

MAUSOLEUM, a monument erected to receive the remains of a deceased person, which may sometimes take the form of a sepulchral chapel. The term originated with the magnificent monument erected by Queen Artemisia in 353 B.C. in memory of her husband King Mausolus. Some remains of this monument were brought to England in 1859 by Sir Charles Newton and placed in the British Museum.

MAUSOLUS (more correctly MAUSSOLLUS), satrap and practically ruler of Caria (377–353 B.C.). The part he took in the revolt against Artaxerxes Mnemon, his conquest of a great part of Lycia, Ionia and of several of the Greek islands, his co-operation with the Rhodians and their allies in the war against Athens, and the removal of his capital from Mylasa, the ancient seat of the Carian kings, to Halicarnassus are the leading facts of his history. He is best known from the tomb erected for him by his widow Artemisia. The architects Satyrus and Pythis, and the sculptors Scopas, Leochares, Bryaxis and Timotheus, finished the work after her death. (*See* HALICARNASSUS.)

MAUVE, ANTON (1838–1888), Dutch landscape painter, was born at Zaandam, the son of a Baptist minister. He studied under Van Os, whose dry academic manner had, however, but little attraction for him. He benefited far more by his intimacy with his friends Jozef Israels and W. Maris. Under their influence he adopted a freer, looser method of painting, and exchanged the brilliant palette of his youthful work for a tender harmony of delicate greys, greens and light blue. He excelled in rendering the soft hazy atmosphere that lingers over the green meadows of Holland, and found his inspiration in the peaceful rural life of the fields and country lanes near Oosterbeek and Wolfhezen, the sand dunes of the coast at Scheveningen, and the country near Laren, where he spent the last years of his life. There are fourteen of Mauve's pictures at the Mesdag Museum at The Hague, and two ("Milking Time" and "A Fishing Boat putting to Sea") at the Ryks Museum in Amsterdam. The Glasgow Corporation Gallery owns his painting of "A Flock of Sheep." The finest and most representative private collection of pictures by Mauve was made by Mr. J. C. J. Drucker, London.

See H. L. Berchenhoff: *Anton Mauve* (Amsterdam 1890).

MAVIS, the name in Scotland for the song-thrush (*Turdus philomelus*), but now little used except in poetry. *See* THRUSH.

MAVROCORDATO, MAVROCORDAT or MAVROGORDATO, the name of a family of Phanariot Greeks, distinguished in the history of Turkey, Rumania and modern Greece. The family was founded by a merchant of Chios, whose son Alexander Mavrocordato (*c.* 1636–1709), became dragoman to the sultan in 1673, and drew up the treaty of Karlowitz (1699). He became a secretary of state, and was created a count of the Holy Roman Empire. His authority, with that of Hussein Kupruli and Rami Pasha, was supreme at the court of Mustapha II., and he ameliorated the condition of the Christians in Turkey. He was disgraced in 1703, but was recalled to court by Sultan Ahmed III. He left some historical, grammatical, etc. treatises of little value.

His son NICHOLAS MAVROCORDATO (1670–1730) was grand dragoman to the Divan (1697), and in 1708 was appointed hospodar (prince) of Moldavia. Deposed, owing to the sultan's suspicions, in favour of Demetrius Cantacuzene, he was restored in 1711, and soon afterwards became hospodar of Walachia. In 1716 he was deposed by the Austrians, but was restored after the peace of Passarowitz. He was the first Greek ruler of the Danubian principalities, and established the system which for a hundred years was to make the name of Greek hateful to the Rumanians. He introduced Greek manners, the Greek language and Greek costume, and set up a splendid court on the Byzantine model. Nicholas founded libraries and was himself the author of a curious work entitled Περὶ καθήκοντων (Bucharest, 1719). He was succeeded as grand dragoman (1709) by his son John (Ioannes), who was for a short while hospodar of Moldavia, and died in 1730.

Nicholas Mavrocordato was succeeded as prince of Walachia in 1730 by his son Constantine who ruled with intervals from 1735 to 1749. He was wounded and taken prisoner at Galati during the Russo-Turkish War, on Nov. 5, 1769, and died in captivity.

PRINCE ALEXANDER MAVROCORDATO (1791–1865), Greek statesman, a descendant of the hospodars, was born at Constantinople on Feb. 11, 1791. In 1812 he went to the court of his uncle Ioannes Caradja, hospodar of Walachia, with whom he passed into exile in Russia and Italy (1817). He was a member of the Hetairia Philike and was among the Phanariot Greeks who hastened to the Morea on the outbreak of the War of Independence in 1821. In January 1822 he presided over the first Greek national assembly at Epidaurus. He commanded the advance of the Greeks into western Hellas, and was defeated at Peta on July 16, but retrieved this disaster somewhat by his successful resistance to the first siege of Missolonghi (Nov. 1822 to Jan. 1823). His English sympathies brought him, in the subsequent strife of factions, into opposition to the "Russian" party headed by Demetrius Ypsilanti and Kolokotrones; and though he held the portfolio of foreign affairs for a short while under the presidency of Petrobey (Petros Mavromichales), he was in retirement until February 1825, when he again became a secretary of state. The landing of Ibrahim Pasha followed, and Mavrocordato again joined the army, only escaping capture in the disaster at Sphagia (Spakteria), on May 9, 1815, by swimming to Navarino. He was vice-president of the National Assembly at Argos (July, 1832), and was appointed by King Otto minister of finance, and in 1833 premier. From 1834 onwards he was Greek envoy at Munich, Berlin, London and—after a short interlude as premier in Greece in 1841—Constantinople. He was again prime minister in 1844 and in 1854–5. He died in Aegina on Aug. 18, 1865.

MAWSON, SIR DOUGLAS: *see* ANTARCTIC REGIONS.

MAX, ADOLPHE (1869–), Belgian politician, was born in Brussels on Dec. 31, 1869. From 1894 to 1903 he was successively provincial councillor of Brabant, councillor of the Commune and alderman of Brussels, and finally burgomaster (1909). In 1914 when the German troops entered Brussels he refused to perform his duties under the authority of the German governor, and demanded complete freedom of action. He protested vigorously against the abuses of the army of occupation, and fought with indomitable energy for the rights of his fellow subjects, and for the reduction of the heavy taxes and requisitions which were imposed on the town. He further founded a central committee to deal with supplies which, under the name of *Le Comité National*, rendered invaluable services to his countrymen. But the German authorities soon took exception to his spirited resistance, and on Sept. 26 1914 he was arrested and imprisoned in the fortress of Namur, and from there was sent into Germany, where he was closely confined. On Nov. 13 1918 he succeeded in escaping and returned to Belgium, where he was welcomed with delirious enthusiasm. Max was elected to the Chamber of Representatives in 1919; he was made minister of state on Nov. 21, 1918, and was also elected member of the Belgian Academy.

MAXENTIUS, MARCUS AURELIUS VALERIUS, Roman emperor from A.D. 306 to 312, was the son of Maximianus Herculius, and the son-in-law of Galerius. He was left out of account in the division of the empire which took place in 305. A variety of causes, however, had produced strong dissatisfaction at Rome with many of the arrangements established by Diocletian, and on Oct. 28, 306, Maxentius headed a rising and summoning his father Maximianus from retirement, captured and killed Valerius Severus and drove Galerius out of Italy when he attacked them. Maxentius quarrelled with his father, and the congress at Carnuntum for 308 again ignored him, but nothing was done to depose him. The death of Galerius in 311 precipitated a conflict; Constantine came to terms with his other rival Licinius, crossed the Alps and struck at Rome. The decisive battle was fought at Saxa Rubra on the passage of the Tiber; Maxentius was defeated,

and drowned in the Tiber (Oct. 27, 312).

See De Broglie, *L'Eglise et l'empire Romain au quatrième siècle* (1856–66), and on the attitude of the Romans towards Christianity generally, app. 8 in vol. ii. of J. B. Bury's edition of Gibbon (Zosimus ii. 9–18; Zonaras xii. 33, xiii. 1; Aurelius Victor, *Epit.* 40; Eutropius, x. 2).

MAXIM, HUDSON (1853–1927), American inventor, was born at Orneville, Me., on Feb. 3, 1853, and completed his academic studies at Kent's Hill, Me. Though his education was but slight, his interest in chemistry led him to wide reading and experimentation in the subject while he worked at other jobs. In 1875 he formulated (published in *Scientific American Supplement*, 1889) an hypothesis of the compound nature of atoms not unlike the atomic theory which was later to be generally accepted by scientists. In 1888 he began to experiment with explosives and in 1890 built a dynamite and powder factory at Maxim, N.J. Here, together with Dr. R. C. Schupphaus, he developed the Maxim-Schupphaus smokeless powder, the first made in the United States and the first to be adopted by the U.S. Government. He next invented a smokeless cannon powder, the cylindrical grains so perforated that it burned with a more rapid combustion, that was used in enormous quantities during the World War. In 1897 he sold his factory and powder inventions to the E. I. DuPont Company, but remained with the company as consulting engineer. He invented "maximite," a high explosive bursting powder which, when placed in torpedoes, resisted the shock of firing and the still greater shock of piercing armour plate without bursting, only to be set off by a delay-action detonating fuse, which was also his invention. Later he perfected a new smokeless powder called "stabillite," on account of its high stability. "Motorite," a self-combustive substance used to propel torpedoes, was also his invention. During the World War he was chairman of the committee on ordnance and explosives of the naval consulting board. Several of his own inventions at this time were donated to the Government.

He published *Science of Poetry* (1910) and *Dynamite Stories* (1916). *The Rise of an American Inventor* (1927) is his life story taken down from conversations by Clifton Johnston.

SIR HIRAM STEVENS MAXIM (1840–1916), his brother, was the inventor of the Maxim automatic gun.

MAXIMA AND MINIMA, in mathematics. By the *maximum* or *minimum* value of an expression or quantity is meant primarily the "greatest" or "least" value that it can receive. In general, however, there are points at which its value ceases to increase and begins to decrease; its value at such a point is called a maximum. So there are points at which its value ceases to decrease and begins to increase; such a value is called a minimum. There may be several such maxima or minima, and such a minimum is not necessarily less than such a maximum. For instance, the expression $(x^2+x+2)/(x-1)$ can take all values from $-\infty$ to -1 and from $+7$ to $+\infty$ but has, so long as x is real, no value between -1 and $+7$. Here -1 is a maximum value, and $+7$ is a minimum value of the expression, though it can be made greater or less than any assignable quantity.

The first general method of investigating maxima and minima seems to have been published in A.D. 1629 by Pierre Fermat. Particular cases had been discussed. Thus Euclid in book III. of the *Elements* finds the greatest and least straight lines that can be drawn from a point to the circumference of a circle, and in book VI. (in a proposition generally omitted from editions of his works) finds the parallelogram of greatest area with a given perimeter. Apollonius investigated the greatest and least distances of a point from the perimeter of a conic section, and discovered them to be the normals, and that their feet were the intersections of the conic with a rectangular hyperbola. Some remarkable theorems on maximum areas are attributed to Zenodorus, and preserved by Pappus and Theon of Alexandria. The most noteworthy of them are the following:—

1. Of polygons of n sides with a given perimeter the regular polygon encloses the greatest area.
2. Of two regular polygons of the same perimeter, that with the greater number of sides encloses the greater area.
3. The circle encloses a greater area than any polygon of the same perimeter.
4. The sum of the areas of two isosceles triangles on given bases, the sum of whose perimeters is given, is greatest when the triangles are similar.
5. Of segments of a circle of given perimeter, the semicircle encloses the greatest area.
6. The sphere is the surface of given area which encloses the greatest volume.

The next problem on maxima and minima of which there appears to be any record occurs in a letter from Regiomontanus to Roder (July 4, 1471), and is a particular numerical example of the problem of finding the point on a given straight line at which two given points subtend a maximum angle. Tartaglia in his *General trattato de numeri et mesuri* (*c.* 1556) gives, without proof, a rule for dividing a number into two parts such that the continued product of the numbers and their difference is a maximum.

Fermat investigated maxima and minima by means of the principle that in the neighbourhood of a maximum or minimum the differences of the values of a function are insensible, a method virtually the same as that of the differential calculus, and of great use in dealing with geometrical maxima and minima. His method was developed by Huygens, Leibniz, Newton and others, and in particular by John Hudde, who investigated maxima and minima of functions of more than one independent variable, and made some attempt to discriminate between maxima and minima, a question first definitely settled, so far as one variable is concerned, by Colin Maclaurin in his *Treatise on Fluxions* (1742). The method of the differential calculus was perfected by Euler and Lagrange.

Jean (Johann) Bernoulli's famous problem of the "brachistochrone," or curve of quickest descent from one point to another under the action of gravity, proposed in 1696, gave rise to a new kind of maximum and minimum problem in which we have to find a curve and not points on a given curve. From these problems arose the "Calculus of Variations." (*See* CALCULUS OF VARIATIONS.)

The method of the differential calculus is theoretically very simple. Let u be a function of several independent variables x_1, $x_2 x_3, \ldots x_n$; if u is a maximum or minimum for the set of values $x_1, x_2, x_3, \ldots x_n$, and u becomes $u+\delta u$, when $x_1, x_2, x_3, \ldots x_n$, receive small increments $\delta x_1, \delta x_2, \ldots \delta x_n$; then δu must have the same sign for all possible values of $\delta x_1, \delta x_2, \ldots \delta x_n$.

$$\text{Now}\quad \delta u = \Sigma\frac{\delta u}{\delta x_1}\delta x_1 + \tfrac{1}{2}\left\{\Sigma\frac{\delta^2 u}{\delta x_1^2}\delta x_1^2 + 2\Sigma\frac{\delta^2 u}{\delta x_1 \delta x_2}\delta x_1\,\delta x_2 \ldots\right\} + \ldots$$

The sign of this expression in general is that of $\Sigma(\delta u/\delta x_1)\delta x_1$, which cannot be one-signed when $\delta x_1, \delta x_2, \ldots \delta x_n$ can take all possible values, for a set of increments $\delta x_1, \delta x_2, \ldots \delta x_n$ will give an opposite sign to the set $-\delta x_1, -\delta x_2, \ldots -\delta x_n$. Hence $\Sigma(\delta u/\delta x_1)\delta x_1$ must vanish for all sets of increments $\delta x_1, \ldots \delta x_n$, and since these are independent, we must have $\delta u/\delta x_1=0$, $\delta u/\delta x_2=0, \ldots \delta u/\delta x_n=0$. A value of u given by a set of solutions of these equations is called a "critical value" of u. The value of δu now becomes

$$\tfrac{1}{2}\left\{\Sigma\frac{\delta^2 u}{\delta x_1^2}\delta x_1^2 + 2\Sigma\frac{\delta^2 u}{\delta x_1\delta x_2}\delta x_1\,dx_2 + \ldots\right\};$$

for u to be a maximum or minimum this must have always the same sign. For the case of a single variable x, corresponding to a value of x given by the equation $du/dx=0$, u is a maximum or minimum as d^2u/dx^2 is negative or positive. If d^2u/dx^2 vanishes, then there is no maximum or minimum unless d^3u/dx^3 vanishes, and there is a maximum or minimum according as d^4u/dx^4 is negative or positive. Generally, if the first differential coefficient which does not vanish is even, there is a maximum or minimum according as this is negative or positive. If it is odd, there is no maximum or minimum.

In the case of several variables, the quadratic

$$\Sigma\frac{\delta^2 u}{\delta x_1^2}\delta x_1^2 + 2\Sigma\frac{\delta^2 u}{\delta x_1\delta x_2}\delta x_1\delta x_2 + \ldots$$

must be one-signed. For the case of two variables the conditions are

$$\frac{\delta^2 u}{\delta x_1^2}\cdot\frac{\delta^2 u}{\delta x_2^2}>\left(\frac{\delta^2 u}{\delta x_1 \delta x_2}\right)^2$$

for a maximum or minimum at all and $\delta^2 u/\delta x_1^2$ and $\delta^2 u/\delta x_2^2$ both negative for a maximum, and both positive for a minimum. It is important to notice that by the quadratic being one-signed is meant that it cannot be made to vanish except when δx_1, δx_2, . . . δx_n all vanish. If, in the case of two variables,

$$\frac{\delta^2 u}{\delta x_1^2}\cdot\frac{\delta^2 u}{\delta x_2^2}=\left(\frac{\delta^2 u}{\delta x_1 \delta x^2}\right)^2$$

then the quadratic is one-signed unless it vanishes, but the value of u is not necessarily a maximum or minimum, and the terms of the third and possibly fourth order must be taken into account.

A critical value usually gives a maximum or minimum in the case of a function of one variable, and often in the case of several independent variables, but such maxima and minima are purely local and the absolutely greatest and least values are not necessarily critical values. If, for example, x is restricted to lie between the values a and b and $\phi'(x)=0$ has no roots in this interval, it follows that $\phi'(x)$ is one-signed as x increases from a to b, so that $\phi(x)$ is increasing or diminishing all the time, and the greatest and least values of $\phi(x)$ are $\phi(a)$ and $\phi(b)$, though neither of them is a critical value. In general, the absolutely greatest and least values of the function may be given by $\phi(a)$ or $\phi(b)$, however many critical values exist.

Full analytical details may be found in any standard treatise on the Calculus. English writers, however, are apt to ignore any but critical values. *See* MATHEMATICAL MODELS. (A. E. J.)

MAXIMIANUS, a Latin elegiac poet of Etruscan birth who flourished during the 6th century A.D. At an advanced age he was sent on an important mission to the East, perhaps by Theodoric. The six elegies extant under his name were written in old age, lamenting the loss of his youth.

Editions by J. C. Wernsdorf, *Poetae latini minores,* vi.; E. Bährens, *Poetae latini minores,* v.; M. Petschenig (1890), in C. F. Ascherson's *Berliner Studien,* xi.; R. Webster (Princeton, 1901). There is an English version (as from Cornelius Gallus), by Hovenden Walker (1689), under the title of *The Impotent Lover.*

MAXIMIANUS, MARCUS AURELIUS VALERIUS, surnamed Herculius, Roman emperor from A.D. 286 to 305, was born at Sirmium in Pannonia. He rose from the ranks to distinction in the army, and having been made Caesar by Diocletian in 285, received the title of Augustus in the following year (April 1, 286). In 287 he suppressed the rising of the peasants (Bagaudae) in Gaul, but he had to acquiesce in the usurpation of Britain by Carausius. After 293 the empire was further divided, and Constantius Chlorus took over the Rhine, while Maximianus had Italy and Africa. In 297 he won a victory in Mauretania, and in 302 he shared at Rome the triumph of Diocletian, the last pageant of the kind ever witnessed there. On May 1, 305, the day of Diocletian's abdication, he also, but without his colleague's sincerity, divested himself of the imperial dignity at Mediolanum (Milan), which had been his capital, and retired to a villa in Lucania; in the following year, however, he was induced by his son Maxentius to reassume the purple. By allying himself with Constantine he made head against Galerius in Italy for a while, and then quarrelled with Maxentius; Diocletian intervened, and Maximianus abdicated again. In Constantine's absence on the Rhine next year (311) he made another attempt; Constantine returned swiftly, drove him from Arles to Marseilles, where he surrendered. Soon afterwards he was found dead.

See Zosimus ii. 7–11; Zonaras xii. 31-33; Eutropius ix. 20, x. 2, 3; Aurelius Victor, p. 39. For the emperor Galerius Valerius Maximianus *see* GALERIUS.

MAXIMILIAN I. (1459–1519), Roman emperor, son of the emperor Frederick III. and Leonora, daughter of Edward, king of Portugal, born at Vienna Neustadt on March 22, 1459. On Aug. 18, 1477, he was married at Ghent to Mary, who had inherited Burgundy and the Netherlands from her father Charles the Bold, duke of Burgundy. He at once undertook the defence of his wife's dominions from an attack by Louis XI., king of France, and defeated the French forces at Guinegatte, the modern Enguinegatte, on Aug. 7, 1479. But Maximilian was regarded with suspicion by the States of the Netherlands, and after suppressing a rising in Gelderland his position was further weakened by the death of his wife on March 27, 1482. He claimed to be recognized as guardian of his young son Philip and as regent of the Netherlands, but some of the States refused to agree to his demands and disorder was general. Maximilian was compelled to assent to the treaty of Arras in 1482 between the States of the Netherlands and Louis XI., which provided that Maximilian's daughter Margaret should marry Charles, the dauphin of France, and have for her dowry Artois and Franche-Comté, two of the provinces in dispute, while the claim of Louis on the duchy of Burgundy was tacitly admitted.

Maximilian did not, however, abandon the struggle in the Netherlands. Having crushed a rebellion at Utrecht, he compelled the burghers of Ghent to restore Philip to him in 1485, and returning to Germany was chosen king of the Romans, or German king, at Frankfort on Feb. 16, 1486, and crowned at Aix-la-Chapelle on April 9. Again in the Netherlands, he made a treaty with Francis II., duke of Brittany, whose independence was threatened by the French regent, Anne of Beaujeu, and the struggle with France was soon renewed. This war was very unpopular with the trading cities of the Netherlands, and early in 1488 Maximilian, having entered Bruges, was detained there as a prisoner for nearly three months, and only set at liberty on the approach of his father with a large force. He delayed his departure for nearly a year and took part in a punitive campaign against his captors and their allies. On his return to Germany he made peace with France at Frankfort in July 1489, and in October several of the States of the Netherlands recognized him as their ruler and as guardian of his son. In March 1490 the county of Tirol was added to his possessions through the abdication of his kinsman, Count Sigismund, and this district soon became his favourite residence.

Meanwhile the king had formed an alliance with Henry VII. king of England, and Ferdinand II., king of Aragon, to defend the possessions of the duchess Anne, daughter and successor of Francis, duke of Brittany. Early in 1490 he was betrothed to the duchess, and later in the same year the marriage was celebrated by proxy; but Brittany was still occupied by French troops, and Maximilian was unable to go to the assistance of his bride. In Dec. 1491 Anne was married to Charles VIII., king of France, and Maximilian's daughter Margaret, who had resided in France since her betrothal, was sent back to her father. Maximilian took no action, being occupied in Hungary, where the death of king Matthias Corvinus had brought about a struggle for this throne. The Roman king, who was an unsuccessful candidate, took up arms, drove out the Hungarians from Austria, and regained Vienna, which had been in the possession of Matthias since 1485; but he was compelled by want of money to retreat, and on Nov. 7, 1491 signed the Treaty of Pressburg with Ladislaus, king of Bohemia, who had obtained the Hungarian throne, agreeing that Maximilian should succeed to the crown in case Ladislaus left no legitimate male issue. Having defeated the invading Turks at Villach in 1492, the king was eager to take revenge upon the king of France; but the States of the Netherlands would afford him no assistance. The German diet was indifferent, and in May 1493 he agreed to the peace of Senlis and regained Artois and Franche-Comté.

In Aug. 1493 the death of the emperor left Maximilian sole ruler of Germany and head of the house of Habsburg; and on March 16, 1494 he married at Innsbruck Bianca Maria Sforza, daughter of Galeazzo Sforza, duke of Milan (d. 1476). Maximilian made an ineffectual appeal to the Christian sovereigns to assist him in driving the Turks from Europe. In 1494 he was again in the Netherlands, where he led an expedition against the rebels of Gelderland, assisted Perkin Warbeck to make a descent upon England, and formally handed over the Government of the Low Countries to Philip. His attention was next turned to Italy, and, alarmed at the progress of Charles VIII. in the peninsula, he signed the league of Venice in March 1495, and about the same time arranged a marriage between his son Philip and Joanna, daughter of Ferdinand and Isabella, king and queen of Castile

and Aragon. In need of help in Italian war the king called the diet to Worms in March 1495 and urged the necessity of checking the progress of Charles; proposals for the better government of the empire were brought forward at Worms as a necessary preliminary to financial and military support. Some reforms were adopted, the public peace was proclaimed without any limitation of time and a general tax was levied. The three succeeding years were mainly occupied with quarrels with the diet, with two invasions of France, and a war in Gelderland against Charles, count of Egmont, who claimed that duchy, and was supported by French troops. The reforms of 1495 were rendered abortive by the refusal of Maximilian to attend the diets or to take any part in the working of the new Constitution, and in 1497 he strengthened his own authority by establishing an Aulic Council (*Reichshofrath*), which he declared was competent to deal with all business of the empire, and about the same time set up a court to centralize the financial administration of Germany.

In Feb. 1499 the king became involved in a war with the Swiss, who had refused to pay the imperial taxes or to furnish a contribution for the Italian expedition. Aided by France they defeated the German troops, and the peace of Basle in Sept. 1499 recognized them as virtually independent of the empire. About this time Maximilian's ally, Ludovico of Milan, was taken prisoner by Louis XII., king of France, and Maximilian was again compelled to ask the diet for help. An elaborate scheme for raising an army was agreed to, and in return a council of regency (*Reichsregiment*) was established, which amounted, in the words of a Venetian envoy, to a deposition of the king. The relations were now very strained between the reforming princes and Maximilian, who, unable to raise an army, refused to attend the meetings of the council at Nuremberg, while both parties treated for peace with France. The hostility of the king rendered the council impotent. He was successful in winning the support of many of the younger princes, and in establishing a new court of justice, the members of which were named by himself.

The negotiations with France ended in the Treaty of Blois, signed in Sept. 1504, when Maximilian's grandson Charles was betrothed to Claude, daughter of Louis XII., and Louis, invested with the duchy of Milan, agreed to aid the king of the Romans to secure the imperial crown. A succession difficulty in Bavaria-Landshut was only decided after Maximilian had taken up arms and narrowly escaped with his life at Regensburg. In the settlement of this question, made in 1505, he secured a considerable increase of territory, and when the king met the diet at Cologne in 1505 he was at the height of his power. His enemies at home were crushed, and their leader, Berthold, elector of Mainz, was dead; while the outlook abroad was more favourable than it had been since his accession.

But whatever hopes of a universal monarchy Maximilian may have had were shattered by the death of his son Philip and the rupture of the Treaty of Blois. The diet of Cologne discussed the question of reform in a halting fashion, but afforded the king supplies for an expedition into Hungary, to aid his ally Ladislaus, and to uphold his own influence in the East. Having established his daughter Margaret as regent for Charles in the Netherlands, Maximilian met the diet at Constance in 1507, when the imperial chamber (*Reichskammergericht*) was revised and took a more permanent form, and help was granted for an expedition to Italy. The king set out for Rome to secure his coronation, but Venice refused to let him pass through her territories; and at Trant, on Feb. 4, 1508, he assumed the title of Roman Emperor Elect, to which he soon received the assent of pope Julius II. He attacked the Venetians, but finding the war unpopular with the trading cities of southern Germany, made a truce with the republic for three years. The Treaty of Blois which contained a secret article providing for an attack on Venice, ripened into the league of Cambray, which was joined by the emperor in Dec. 1509. He soon took the field, but after his failure to capture Padua the league broke up; and his sole ally, the French king, joined him in calling a general council at Pisa to discuss the question of Church reform.

A breach with pope Julius followed, and at this time Maximilian appears to have entertained, perhaps quite seriously, the idea of seating himself in the chair of St. Peter. After a period of vacillation he deserted Louis and joined the Holy League, which had been formed to expel the French from Italy; but unable to raise troops, he served with the English forces as a volunteer and was present at the battle of the Spurs near Thérouanne on Aug. 16, 1513. In 1500 the diet had divided Germany into six circles, for the maintenance of peace, to which the emperor at the diet of Cologne in 1512 added four others. Having made an alliance with Christian II., king of Denmark, and interfered to protect the Teutonic Order against Sigismund I., king of Poland, Maximilian was again in Italy early in 1516 fighting the French who had overrun Milan. His want of success compelled him on Dec. 4, 1516, to sign the Treaty of Brussels, which left Milan in the hands of the French king, while Verona was soon afterwards transferred to Venice. He attempted in vain to secure the election of his grandson Charles as king of the Romans. Leaving the diet of Augsburg (1518) he travelled to Wels in Upper Austria, where he died on Jan. 12, 1519. He was buried in the church of St. George in Vienna Neustadt.

Maximilian had many excellent personal qualities. Simple in his habits, conciliatory in his bearing, and catholic in his tastes, he enjoyed great popularity and rarely made a personal enemy. He was a skilled knight and a daring huntsman, and although not a great general, was intrepid on the field of battle. He reorganized the University of Vienna and encouraged the development of the universities of Ingolstadt and Freiburg. He was the author of military reforms, which included the establishment of standing troops, called *Landsknechte*. He was continually devising plans for the better government of Austria, and although they ended in failure, he established the unity of the Austrian dominions. Maximilian has been called the second founder of the house of Habsburg, and certainly by bringing about marriages between Charles and Joanna and between his grandson Ferdinand and Anna, daughter of Ladislaus, king of Hungary and Bohemia, he paved the way for the vast empire of Charles V. and for the influence of the Habsburgs in eastern Europe.

But Maximilian was at once reckless and unstable. For absurd and impracticable schemes in Italy and in other places, he at times neglected even Germany, and sought to involve its princes in wars undertaken solely for private aggrandizement or personal jealousy. Ignoring his responsibilities as ruler of Germany, he only considered the question of its government when in need of money and support from the princes. As the "last of the knights" he could not see that the old order of society was passing away and a new order arising, while he was fascinated by the glitter of the mediaeval empire and spent the better part of his life in vague schemes for its revival. As "a gifted amateur in politics" he increased the disorder of Germany and Italy and exposed himself and the empire to the jeers of Europe.

Maximilian was also a writer of books, and his writings display his inordinate vanity. His *Geheimes Jagdbuch*, containing about 2,500 words, is a treatise purporting to teach his grandsons the art of hunting. He inspired the production of *The Dangers and Adventures of the Famous Hero and Knight Sir Teuerdank*, an allegorical poem describing his adventures on his journey to marry Mary of Burgundy. It was first published at Nuremberg by Melchior Pfintzing in 1517, and was adorned with woodcuts by Hans Leonhard Schaufelein. The *Weisskunig* was long regarded as the work of the emperor's secretary, Marx Treitzsaurwein, but it is now believed that the greater part of the book at least is the work of the emperor himself. It is an unfinished autobiography containing an account of the achievements of Maximilian, who is called "the young white king." It was first published at Vienna in 1775. He also is responsible for *Freydal*, an allegorical account of the tournaments in which he took part during his wooing of Mary of Burgundy; *Ehrenpforten*, *Triumphwagen* and *Der weisen Könige Stammbaum*, books concerning his own history and that of the house of Habsburg, and works on various subjects, as *Das Stahlbuch*, *Die Baumeisterei* and *Die Gärtnerei*. These works are all profusely illustrated, some by Albrecht Dürer.

A facsimile of the original editions of Maximilian's autobiographical and semi-autobiographical works has been published in nine volumes in the *Jahrbücher der kunsthistorischen Sammlungen des Kaiserhauses* (Vienna, 1880–88). For this edition S. Laschitzer wrote an introduction to *Sir Teuerdank*, Q. von Leitner to *Freydal*, and N. A. von Schultz to *Der Weisskunig*. The Holbein society issued a facsimile of *Sir Teuerdank* (London, 1884) and *Triumphwagen* (1883).

See *Correspondance de l'empereur Maximilien I. et de Marguerite*

d'Autriche, 1507–1519, ed. A. G. le Glay (1839); *Maximilians I. vertraulicher Briefwechsel mit Sigmund Prüschenk*, ed. V. von Kraus (Innsbruck, 1875); J. Chmel, *Urkunden, Briefe und Aktenstücke zur Geschichte Maximilians I. und seiner Zeit*. (Stuttgart, 1845) and *Aktenstücke und Briefe zur Geschichte des Hauses Habsburg im Zeitalter Maximilians I.* (Vienna, 1854–58); K. Klüpfel, *Kaiser Maximilian I.* (1864); H. Ulmann, *Kaiser Maximilian I.* (Stuttgart, 1884); L. P. Gachard, *Lettres inédites de Maximilien I. sur les affaires des Pays Bas* (Brussels, 1851–52); L. von Ranke, *Geschichte der romanischen und germanischen Völker, 1494–1514* (Leipzig, 1874); R. W. S. Watson, *Maximilian I.* (1902); A. Jäger, *Über Kaiser Maximilians I. Verhältnis zum Papstthum* (Vienna, 1854); H. Ulmann, *Kaiser Maximilians I. Absichten auf das Papstthum* (Stuttgart, 1888), and A. Schulte, *Kaiser Maximilian I. als Kandidat für den päpstlichen Stuhl* (Leipzig, 1906); C. Hare, *Maximilian the Dreamer* (1913).

MAXIMILIAN II. (1527–1576), Roman emperor, was the eldest son of the emperor Ferdinand I. by his wife Anne, daughter of Ladislaus, king of Hungary and Bohemia, and was born in Vienna on July 31, 1527. Educated principally in Spain, he gained some experience of warfare during the campaign of Charles V. against France in 1544, and also during the war of the league of Schmalkalden, and soon began to take part in imperial business. Having in Sept. 1548 married his cousin Maria, daughter of Charles V., he acted as the emperor's representative in Spain from 1548 to 1550, returning to Germany in December 1550 in order to take part in the discussion over the imperial succession. Charles V. wished his son Philip (afterwards king of Spain) to succeed him as emperor, but his brother Ferdinand, who had already been designated as the next occupant of the imperial throne, and Maximilian objected to this proposal. At length a compromise was reached. Philip was to succeed Ferdinand, but during the former's reign Maximilian, as king of the Romans, was to govern Germany. This arrangement was not carried out, but the insistence of the emperor disturbed the harmonious relations between the two branches of the Habsburg family; and Maximilian's illness in 1552 was even attributed to poison given to him in the interests of his cousin and brother-in-law, Philip of Spain. He took up his residence in Vienna, and was engaged mainly in the government of the Austrian dominions and their defence against the Turks. The religious views of the king of Bohemia, as Maximilian had been called since his recognition as the future ruler of that country in 1549, had always been somewhat uncertain, and he had probably learned something of Lutheranism in his youth; but his amicable relations with the Protestant princes were probably due to political considerations. Maximilian remained an adherent of the older faith, although his views were tinged with Lutheranism until the end of his life. In November 1562 Maximilian was chosen king of the Romans, or German king, at Frankfort, where he was crowned a few days later, after assuring the Catholic electors of his fidelity to their faith, and promising the Protestant electors that he would publicly accept the confession of Augsburg when he became emperor. He also took the usual oath to protect the Church, and his election was afterwards confirmed by the papacy. In Sept. 1563 he was crowned king of Hungary, and on his father's death, in July 1564, succeeded to the empire and to the kingdoms of Hungary and Bohemia.

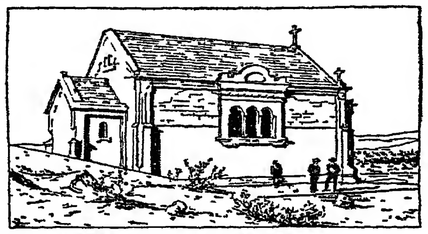
The new emperor granted religious liberty to the Lutheran nobles and knights in Austria, and refused to allow the publication of the decrees of the council of Trent. Amid general expectations on the part of the Protestants he met his first Diet at Augsburg in March 1566. He refused to accede to the demands of the Lutheran princes; on the other hand, although the increase of sectarianism was discussed, no decisive steps were taken to suppress it, and the only result of the meeting was a grant of assistance for the Turkish War, which had just been renewed. Collecting a large and splendid army Maximilian marched to defend his territories; but no decisive engagement had taken place when a truce was made in 1568, and the emperor continued to pay tribute to the sultan for Hungary. Meanwhile the relations between Maximilian and Philip of Spain had improved; and the emperor's increasingly cautious and moderate attitude in religious matters was doubtless due to the fact that the death of Philip's son, Don Carlos, had opened the way for the succession of Maximilian, or of one of his sons, to the Spanish throne. Evidence of this friendly feeling was given in 1570, when the emperor's daughter, Anne, became the fourth wife of Philip; but Maximilian was unable to moderate the harsh proceedings of the Spanish king against the revolting inhabitants of the Netherlands. In 1570 the emperor met the diet at Spires and asked for aid to place his eastern borders in a state of defence, and also for power to repress the disorder caused by troops in the service of foreign powers passing through Germany. He proposed that his consent should be necessary before any soldiers for foreign service were recruited in the empire; but the estates were unwilling to strengthen the imperial authority, the Protestant princes regarded the suggestion as an attempt to prevent them from assisting their coreligionists in France and the Netherlands, and nothing was done in this direction, although some assistance was voted for the defence of Austria. The religious demands of the Protestants were still unsatisfied, while the policy of toleration had failed to give peace to Austria. His last important act was to make a bid for the throne of Poland, either for himself or for his son Ernest. In December 1575 he was elected, but the diet which met at Regensburg was loath to assist; and on Oct. 12, 1576, the emperor died, refusing on his deathbed to receive the last sacraments of the Church which were offered him.

By his wife Maria he had a family of nine sons and six daughters. He was succeeded by his eldest surviving son, Rudolph, who had been chosen king of the Romans in October, 1575. Another of his sons, Matthias, also became emperor, three others, Ernest, Albert and Maximilian, took some part in the government of the Habsburg territories or of the Netherlands. His daughter, Elizabeth, eventually was married to Charles IX., King of France.

The religious attitude of Maximilian has given rise to much discussion, and on this subject *see* O. H. Hopfen, *Maximilian II. und der Kompromisskatholizismus* (Munich, 1895); C. Haupt, *Melanchthons und seiner Lehrer Einfluss auf Maximilian II.* (Wittenberg, 1897); F. Walter, *Die Wahl Maximilians II.* (Heidelberg, 1892); W. Goetz, *Maximilians II. Wahl zum römischen Könige* (Würzburg, 1891), and T. J. Scherg, *Über die religiöse Entwickelung Kaiser Maximilians II. bis zu seiner Wahl zum römischen Könige* (Würzburg, 1903). For a more general account of his life and work see *Briefe und Akten zur Geschichte Maximilians II.*, edited by W. E. Schwarz (Paderborn, 1889–91); M. Koch, *Quellen zur Geschichte des Kaisers Maximilian II. in Archiven gesammelt* (Leipzig, 1857–61); R. Holtzmann, *Kaiser Maximilian II. bis zu seiner Thronbesteigung* (Berlin, 1903); E. Wertheimer, *Zur Geschichte der Türkenkriege Maximilians II.* (Vienna, 1875); L. von Ranke, *Über die Zeiten Ferdinands I. und Maximilians II.* in Band VII. of his *Sämmtliche Werke* (Leipzig, 1874), and J. Janssen, *Geschichte des deutschen Volkes seit dem Ausgang des Mittelalters*, Bände IV. to VIII. (Freiburg, 1885–94), Eng. trans. by M. A. Mitchell and A. M. Christie (1896 fol.).

MAXIMILIAN (Ferdinand Maximilian) (1832–1867), emperor of Mexico, was born in Vienna on July 6, 1832, the second son of Archduke Francis Charles, and brother of the Emperor Francis Joseph. After an excellent education, he entered the navy and as first in command was largely responsible for its rehabilitation, and for the growth of Trieste as a naval centre. He was appointed governor-general of the Lombardo-Venetian kingdom in 1857, but in 1859 was summarily relieved of his post. In 1857 he married Princess Charlotte of Belgium. As early as 1859 he was approached by Mexican exiles relative to his candidature for an imperial throne in Mexico, and in Oct. 1863 he was formally offered the crown, which had been created by French armed intervention. (*See* MEXICO.) He accepted it on April 9, 1864, after renouncing his imperial rights in Austria, arrived in Mexico on May 28 and entered Mexico City on June 12. From the beginning, the experiment was doomed, for politically, strategically and economically Maximilian's position was impossible. The country was opposed to him; the liberals refused to recognize his government, though he made several attempts to conciliate them; and the conservatives and clericals were immediately alienated by his liberal measures. Financially and politically he was wholly dependent upon France, without resources with which either to pay his debts or raise armies. Nor was he, personally, fitted to cope with the problem; poor judgment, vacillation and extravagance marked his administration from the first. During 1864 and 1865 his foreign troops reduced the country to subjection, driving

the constitutional government of Juárez almost to the Rio Grande, and on Oct. 3, 1865, he was induced to issue a decree declaring Juárez and his supporters bandits. But in Dec. 1865, the United States, having emerged successfully from the Civil War, demanded the withdrawal of French troops from Mexico. Napoleon acceded in Jan. 1866, and the republican forces commenced their reconquest. The Empress Charlotte went to Europe in July 1866, in a desperate attempt to re-enlist the aid of Napoleon and the pope; she failed and the strain proved so great that she lost her mind. In October, Maximilian, determined to abdicate, fled to Orizaba, but was prevailed upon to return, and in Feb. 1867, assuming personal command of his forces, transferred his headquarters from Mexico City to Querétaro, a lonely figure in the welter of intrigue, selfishness and corruption which engulfed him. The last of the French forces retired in March; and on May 15, Querétaro was betrayed to the republican army. Napoleon's agents had made repeated efforts to secure Maximilian's escape, but he refused to save himself. He was courtmartialled, convicted, and despite universal pleas for mercy, was shot on June 19. The Empress Charlotte died at the Château de Bouchout, near Brussels, on Jan. 19, 1927, having never fully recovered her reason. (*See* JUAREZ, MEXICO.)



BY COURTESY OF C. W. HACKETT
MAXIMILIAN CHAPEL, BUILT AT THE PLACE WHERE MAXIMILIAN WAS SHOT, FROM AN ETCHING BY FRANZ JOSEPH

There is a very good account of the whole Maximilian episode by Egon Caesar, Count Corti: *Maximilian and Charlotte of Mexico* (New York, 1928), which includes an exhaustive bibliography.
(W. B. P.)

MAXIMILIAN I. (1573–1651), called "the Great," elector and duke of Bavaria, eldest son of William V. of Bavaria, was born at Munich on April 17, 1573. He married in 1595 his cousin, Elizabeth, daughter of Charles II., duke of Lorraine, and became duke of Bavaria upon his father's abdication in 1597. He refrained from any interference in German politics until 1607, when he was entrusted with the duty of executing the imperial ban against the free city of Donauwörth, a Protestant stronghold. In Dec. 1607 his troops occupied the city, and steps were taken to restore the older faith. A union of Protestant princes, formed to defend their interests, was met in 1609 by the establishment of a league, in the formation of which Maximilian took an important part. An army was collected, but his policy was strictly defensive and he refused to allow the league to become a tool in the hands of the house of Habsburg. Dissensions among his colleagues led the duke to resign his office in 1616, but he returned to the league about two years later.

After the outbreak of the Thirty Years' War Maximilian made a treaty with the emperor Ferdinand II. in Oct. 1619, and in return for large concessions placed the forces of the league at the emperor's service. He made a treaty of neutrality with the Protestant Union, and occupied Upper Austria as security for the expenses of the campaign. On Nov. 8, 1620, his troops under Count Tilly defeated the forces of Frederick, king of Bohemia, at the White Hill near Prague. Tilly then devastated the Rhenish Palatinate, and in Feb. 1623, Maximilian was formally invested with the electoral dignity and the attendant office of imperial steward, which had been enjoyed since 1356 by the counts palatine of the Rhine. After receiving the Upper Palatinate and restoring Upper Austria to Ferdinand, Maximilian became leader of the party which sought to bring about Wallenstein's dismissal from the imperial service. At the diet of Regensburg in 1630 Ferdinand was compelled to assent to this demand, but the sequel was disastrous both for Bavaria and its ruler. Early in 1632 the Swedes marched into the duchy and occupied Munich, and Maximilian had to place himself under the orders of Wallenstein, now restored to the command of the emperor's forces. The ravages of the Swedes and their French allies induced the elector to enter into negotiations for peace with Gustavus Adolphus and Cardinal Richelieu. He also proposed to placate the Protestants by modifying the Restitution edict of 1629; but these efforts were abortive. In March 1647 he concluded an armistice with France and Sweden at Ulm, but the entreaties of the emperor Ferdinand III. led him to disregard his undertaking. Bavaria was again ravaged, and the elector's forces defeated in May 1648 at Zusmarshausen. By the treaty of Westphalia it was agreed that Maximilian should retain the electoral dignity, which was made hereditary in his family; and the Upper Palatinate was incorporated with Bavaria. The elector died at Ingolstadt on Sept. 27, 1651.

See F. A. W. Schreiber, *Maximilian I. der Katholische Kurfürst von Bayern, und der dreissigjährige Krieg* (Munich, 1868); F. Stieve, *Kurfürst Maximilian I. von Bayern* (Munich, 1882); M. Högl, *Die Bekehrung der Oberpfalz durch Kurfürst Maximilian I.* (Regensburg, 1903).

MAXIMILIAN I. (MAXIMILIAN JOSEPH) (1756–1825), king of Bavaria, the son of the count palatine Frederick of Zweibrücken-Birkenfeld, was born May 27, 1756. He took service in 1777 as a colonel in the French army, and rose rapidly to the rank of major-general. From 1782 to 1789 he was stationed at Strasbourg, but at the outbreak of the revolution he exchanged the French for the Austrian service, taking part in the opening campaigns of the revolutionary wars. On April 1, 1795 he succeeded his brother, Charles II., as duke of Zweibrücken, and on Feb. 16, 1799 became elector of Bavaria on the extinction of the Sulzbach line with the death of the elector Charles Theodore.

The sympathy with France and with French ideas which characterized his reign was at once manifested. In the newly organized ministry Count von Montgelas (*q.v.*) was the most potent influence. Agriculture and commerce were fostered, the laws were ameliorated, a new criminal code drawn up, taxes and imposts equalized without regard to traditional privileges, while a number of religious houses were suppressed and their revenues used for educational and other useful purposes. In foreign politics Maximilian Joseph's attitude was from the German point of view less commendable. With the growing sentiment of German nationality he had from first to last no sympathy, and his attitude throughout was dictated by wholly dynastic, or at least Bavarian, considerations. Until 1813 he was the most faithful of Napoleon's German allies, the relation being cemented by the marriage of his daughter to Eugène Beauharnais. His reward came with the Treaty of Pressburg (Dec. 26, 1805), by the terms of which he was to receive the royal title and important territorial acquisitions in Swabia and Franconia to round off his kingdom. He assumed the style of king on Jan. 1, 1806.

The new king of Bavaria was the most important member of the Confederation of the Rhine, and remained Napoleon's ally until the eve of the battle of Leipzig, when by the convention of Ried (Oct. 8, 1813) he made the guarantee of the integrity of his kingdom the price of his joining the Allies. By the first treaty of Paris (June 3, 1814), however, he ceded Tirol to Austria in exchange for the former duchy of Würzburg. At the congress of Vienna, which he attended in person, Maximilian had to make further concessions to Austria, ceding the quarters of the Inn and Hausruck in return for a part of the old Palatinate. The king fought hard to maintain the contiguity of the Bavarian territories as guaranteed at Ried; but the most he could obtain was an assurance from Metternich in the matter of the Baden succession, in which he was also disappointed (*see* BADEN: *History*).

At Vienna and afterwards Maximilian opposed any reconstitution of Germany which should endanger the independence of Bavaria, and his insistence on full sovereignty for the German reigning princes contributed to the loose and weak organization of the new German Confederation. The Federal Act of the Vienna congress was proclaimed in Bavaria, not as a law but as an international treaty. It was partly to secure popular support in his resistance of any interference of the federal diet in the internal affairs of Bavaria, partly to give unity to his somewhat heterogeneous territories, that Maximilian on May 26, 1818 granted a liberal constitution to his people. Montgelas had fallen in 1817, and Maximilian had also reversed his ecclesiastical policy, signing on Oct. 24, 1817 a concordat with Rome by which the powers of the clergy were restored. The new parliament proved so intract-

able that in 1819 Maximilian appealed to the powers against his own creation; but his Bavarian "particularism" and his genuine popular sympathies prevented him from allowing the Carlsbad decrees to be strictly enforced within his dominions. The suspects arrested by order of the Mainz Commission he examined himself, with the result that in many cases the whole proceedings were quashed, and in not a few the accused dismissed with a present of money. Maximilian died on Oct. 13, 1825, and was succeeded by his son Louis I.

In private life Maximilian was kindly and simple. He loved to play the part of *Landesvater*, walking about the streets of his capital *en bourgeois* and entering into conversation with all ranks of his subjects, by whom he was regarded with great affection. He was twice married: (1) in 1785 to Princess Wilhelmine Auguste of Hesse-Darmstadt, (2) in 1797 to Princess Caroline Friederike of Baden.

See G. Freiherr von Lerchenfeld, *Gesch. Bayerns unter König Maximilian Joseph I.* (1854); J. M. Söltl, *Max Joseph, König von Bayern* (Stuttgart, 1837); L. von Kobell, *Unter den vier ersten Konigen Bayerns. Nach Briefen und eigenen Erinnerungen* (Munich, 1894); A. Steinberger, *Vater Max, der erste Bayernkönig* (1906).

MAXIMILIAN II. (1811–1864), king of Bavaria, son of king Louis I. and of Theresa of Saxe-Hildburghausen, was born on Nov. 28, 1811. After studying at Göttingen and Berlin and travelling in Germany, Italy and Greece, he was introduced by his father into the council of State (1836). As crown prince, in the château of Hohenschwangau near Füssen, he gathered about him an intimate society of artists and men of learning, and devoted his time to scientific and historical study. When the abdication of Louis I. (March 28, 1848) called him suddenly to the throne, his choice of ministers promised a liberal régime. But he strenuously opposed the unionist plans of the Frankfort parliament, refused to recognize the imperial constitution devised by it, and assisted Austria in restoring the federal diet and in carrying out the federal execution in Hesse and Holstein. Although, however, from 1850 onwards his government tended in the direction of absolutism, he refused to become the tool of the clerical reaction, and even incurred the bitter criticism of the Ultramontanes by inviting men of learning and science (*e.g.,* Liebig and Sybel) to Munich, regardless of their religious views. Finally, in 1859, he dismissed the reactionary ministry of von der Pfordten, in favour of a moderate constitutional Government. In his German policy he hoped to attain the union of the princes against the perilous rivalry of Austria and Prussia by the creation of a league of the "middle" and small states—the so-called Trias. In 1863, however, he supported the project of reform proposed by Austria at the Diet of Princes at Frankfort. The failure of this proposal, and the attitude of Austria towards the Confederation and in the Schleswig-Holstein question, undeceived him; but before the outbreak of the war with Denmark he died suddenly at Munich on March 10, 1864. By his wife, Maria Hedwig, daughter of Prince William of Prussia, Maximilian had two sons, Louis II., king of Bavaria, and Otto, king of Bavaria, both of whom lost their reason.

See J. M. Söltl, *Max der Zweite, König von Bayern* (Munich, 1865); biography by G. K. Heigel in *Allgem. Deutsche Biographie,* vol. xxi. (Leipzig, 1885). Maximilian's correspondence with Schlegel was published at Stuttgart in 1890.

MAXIMILIAN (1867–1929), prince of Baden, born July 10, 1867 at Baden-Baden, was a son of Prince William of Baden. As the nearest agnate to the reigning grand duke, of whom he was a cousin twice removed, he was heir presumptive to the grand ducal throne. From 1907 to 1918 he was president of the first chamber of the Baden diet. During the World War Prince Max did much to improve conditions for British prisoners in Germany, as also for German prisoners, especially in Russia. On Oct. 3, 1918, when the old military and political system in Germany was on the verge of collapse, he was appointed Imperial Chancellor. It fell to his lot to initiate the negotiations for the Armistice, and also to carry through in hot haste those alterations in the old constitution which had long been demanded by the Liberals and the Socialists, but which now came too late to avert the fate of the empire and the Prussian monarchy. It also became his duty to put pressure upon the emperor in order to induce him to abdicate. As the imperial decision was delayed from day to day and the revolution became imminent, he declared on Nov. 9, 1918, the abdication of William II. as German Emperor and as King of Prussia. It was clear that the Hohenzollern dynasty was doomed; and Prince Max handed over the Government to the majority Socialist leader Ebert, who became the president of the German *Reich.* He continued, after the abdication of the grand duke, to reside at Karlsruhe, and Schloss Salem, Lake Constance. In defence of his work he published *Erinnerungen* (1927, Eng. trans., 1928). He died at Constance, Germany, Nov. 6, 1929.

MAXIMINUS, GAIUS IULIUS VERUS, Roman emperor from A.D. 235 to 238, was a Thracian shepherd, whose immense strength attracted the notice of Septimius Severus. He entered the army, and rose from the ranks to be commander of the fourth legion (under Alexander Severus), and then to the command of the army on the Rhine. On March 19, 235, he was proclaimed emperor by the soldiers, and Alexander was murdered. The three years of Maximinus' reign were spent in warfare on the Rhine and Danube; his work in the provinces, in organizing the frontiers and building roads, was invaluable. But he has left an evil reputation because he had no predilection for Italy, and no sympathy either with the Senate or the Roman populace, whom he governed somewhat severely, by his praetorian praefect, Vitalianus. Revolt eventually broke out in Africa under the Gordians (*q.v.*), and spread to Italy. Maximinus was delayed by a campaign in Pannonia the following spring (238), when he crossed the Julian Alps and besieged Aquileia. He was murdered by a conspiracy of the praetorians (? June 17).

Capitolinus, *Maximini duo;* Herodian vi. 8, vii., viii., 1–5; Zosimus i. 13–15; Gibbon (ed. Bury).

MAXIMINUS [MAXIMIN], **GALERIUS VALERIUS,** Roman emperor from A.D. 308 to 314, was originally an Illyrian shepherd named Daia. He rose to high distinction in the army, and in 305 he was raised by his uncle, Galerius, to the rank of Caesar, with the government of Syria and Egypt. In 308, after the elevation of Licinius, he insisted on receiving the title of Augustus; on the death of Galerius, in 311, he succeeded to the supreme command of the provinces of Asia, and when Licinius and Constantine began to make common cause with one another Maximinus entered into a secret alliance with Maxentius. He came to an open rupture with Licinius in 313, sustained a crushing defeat in the neighbourhood of Heraclea Pontica on April 30, and fled, first to Nicomedia and afterwards to Tarsus, where he died in August following. *See* MAXENTIUS.

See Zosimus ii. 8; Aurelius Victor, *Epit.* 40.

MAXIMS, LEGAL. A maxim is an established principle or proposition. The Latin term *maxima* is not to be found in Roman law with any meaning exactly analogous to that of a legal maxim in the modern sense of the word, but the treatises of many of the Roman jurists on *regulae, definitiones* and *sententiae juris* are in some measure, collections of maxims. Fortescue (*De laudibus,* c. 8) and Du Cange treat *maxima* and *regula* as identical. The attitude of early English commentators towards the maxims of the law was one of unmingled adulation (*see* Bacon's preface to his *Collection of Maxims*). A similar note was sounded in Scotland. In later times less value has been attached to the maxims of the law, as the development of civilization and the increasing complexity of business relations have shown the necessity of qualifying the propositions which they enunciate (*see* Stephen, *Hist. Crim. Law,* ii. 94 *n*: *Yarmouth* v. *France,* 1887, 19 Q.B.D., per Lord Esher at p. 653, and American authorities collected in Bouvier's *Law Dict. s.v.* "Maxim").

A brief reference need only be made here, with examples by way of illustration, to the field which the maxims of the law cover. Commencing with rules founded on public policy, we may note the famous principle *Salus populi suprema lex,* "the public welfare is the highest law." It is on this maxim that the coercive action of the State towards individual liberty in a hundred matters is based. Among the maxims relating to the Crown, the most important are *Rex non potest peccare*—"the king can do no wrong"—which enshrines the principle of ministerial responsibility, and *Nullum tempus occurrit regi*—"lapse of time does not bar the Crown," a

maxim qualified by various enactments in modern times. Passing to the judicial office and the administration of justice, we may refer to the rules—*Audi alteram partem*—a proposition too familiar to need either translation or comment; *Nemo debet esse judex in propriâ suâ causâ*—"no man ought to be judge in his own cause"—a maxim which French law and the legal systems based upon or allied to it have embodied in an elaborate network of rules for judicial challenge. The maxim *Boni judicis est ampliare jurisdictionem* is certainly erroneous as it stands, as a judge has no right to "extend his jurisdiction." If *justitiam* be substituted for *jurisdictionem*, as Lord Mansfield said it should be, the maxim is near the truth. A group of maxims supposed to embody certain fundamental principles of legal right and obligations may next be referred to: (a) *Ubi jus ibi remedium*—a maxim to which the evolution of the flexible "action on the case," by which wrongs unknown to the "original writs" were dealt with, was historically due, but which must be taken with the gloss *Damnum absque injuria*—"there are forms of actual damage which do not constitute legal injury" for which the law does not supply any remedy; (b) *Actus Dei nemini facit injuriam*—and its allied maxim, *Lex non cogit ad impossibilia*—upon which the whole doctrine of *vis major* (*force mejeure*) and impossible conditions in the law of contract has been built up. In this category may also be classed *Volenti non fit injuria*, out of which sprang the theory—now profoundly modified by statute—of "common employment" in the law of employers' liability (see *Smith* v. *Baker*, 1891, A.C. 325). Other maxims deal with rights of property—*Qui prior est tempore, potior est jure*, which consecrates the position of the *beati possidentes* alike in municipal and in international law, and *Sic utere tuo ut alienum non laedas*, which has played its part in the determination of the rights of adjacent owners (see *Rylands* v. *Fletcher*, L.R 3 H.L. 330). In the laws of family relations there is the maxim *Pater is est quem nuptiae demonstrant*, on which, in most civilized countries, the presumption of legitimacy depends (see *Russell* v. *Russell*, 1924, A.C. 687). In the interpretation of written instruments, the maxim *Noscitur a sociis*, which proclaims the importance of the context, still applies. So do the rules *Expressio unius est exclusio alterius*—"often a valuable servant, but a dangerous master" (*Colquhoun* v. *Brooks*, 19 Q.B.D 406) and *Contemporanea expositio est optima et fortissima in lege*, which lets in evidence of contemporaneous user as an aid to the interpretation of statutes or documents (see *Van Diemen's Land Co.* v. *Table Cape Marine Board*, 1906, A.C. 92, 98; and *Reaa* v. *Lincoln, Bishop of*, 1892, A.C. 644). We may conclude this sketch with a miscellaneous summary: *Caveat emptor*, "let the purchaser beware"; *Qui facit per alium facit per se*, which affirms the principal's liability for the acts of his agent; *Ignorantia juris neminem excusat*, on which rests the ordinary citizen's obligation to know the law, and *Actio personalis moritur cum persona*, a rule now mainly confined to actions of tort and limited by numerous exceptions. For maxims of equity *see* EQUITY.

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MAXIM SILENCER. A device, invented in 1908 by Hiram Percy Maxim, an American, for suppressing the sound of discharge of firearms. Attached to any tight-breech firearm, such as a rifle, it checked the sudden liberation of the powder gases into the atmosphere by imparting a whirling motion to them, which caused them to fly out from the central hole by centrifugal force. Their escape could thus not occur until they slowed down, at which time they escaped noiselessly. Meanwhile, the same mechanism that caused the powder gases to acquire a whirling motion also served as a series of acoustic resonating chambers, which acted to set up interfering resonance and trap the sound frequencies present.

Originally, the device was considered as a menace to public safety, since it was believed by many that it would chiefly serve criminals. Many of the States in the United States passed laws prohibiting its sale and use, and several countries prohibited its importation. However, this was due to the great public interest taken in the invention when it was first announced, and a lack of understanding of firearms. The arms used by criminals are almost invariably small arms, such as revolvers and pistols. The revolver cannot be silenced by the Maxim Silencer because it is not a tight-breech mechanism. Having a cylinder and a barrel, and of necessity a joint between the two latter, a leak is created. When a silencer is applied to the muzzle of the barrel of a revolver, the powder gases and noise escape at this leak. The automatic pistol cannot be silenced because of the mechanical noise made by the automatic breech mechanism. Only single shot pistols and rifles can be silenced by the Maxim Silencer.

The silencing of all forms of noises that issue from a pipe was later accomplished by the Maxim Silencer, and at the present time it is the accepted means for overcoming the noise of the exhaust of Diesel engines, gas and gasolene engines, steam engines, safety valves, air and steam releases and also the intakes or suctions of air compressors and blowers. Its construction permits gases to flow freely through, but sound is trapped and caused to dissipate itself inside the device.

MAXIMUS, ST. (*c.* 580–662), abbot of Chrysopolis, known as "the Confessor" from his orthodox zeal in the Monothelite (*q.v.*) controversy, or as "the monk," was born of noble parentage at Constantinople about the year 580. He became private secretary to the emperor Heraclius in 610. In 630 he entered the monastery of Chrysopolis (Scutari), of which he became abbot In 633 he was one of the party of Sophronius of Jerusalem (the chief original opponent of the Monothelites) at the council of Alexandria; and in 645 he was again in Africa, when he disputed with Pyrrhus, the deposed and banished patriarch of Constantinople. In the following year several African synods, held under the influence of Maximus, declared for orthodoxy. In 649 he went to Rome, after the accession of Martin I., who in October of that year held the (first) Lateran synod, by which not only the Monothelite doctrine but also the moderating *ecthesis* of Heraclius and *typus* of Constans II. were anathematized.

About 653 Maximus was apprehended (together with the pope) by order of Constans and carried a prisoner to Constantinople. In 655 he was banished to Byzia in Thrace, and afterwards to Perberis. In 662 he was again brought to Constantinople and was condemned by a synod to be scourged, to have his tongue cut out by the root, and to have his right hand chopped off. He was then banished to Lazica, where he died on Aug. 13, 662. He is venerated as a saint both in the Greek and in the Latin Churches.

The most important of the works of Maximus will be found in Migne, *Patrologia graeca*, xc., xci., together with an anonymous life; an exhaustive list in Wagenmann's article in vol. xii. (1903) of Hauck-Herzog's *Realencyklopädie* where the following classification is adopted: (*a*) exegetical, (*b*) scholia on the Fathers, (*c*) dogmatic and controversial, (*d*) ethical and ascetic, (*e*) miscellaneous. The details of the disputation with Pyrrhus and of the martyrdom are given very fully and clearly in Hefele's *Conciliengeschichte*, iii.

MAXIMUS, the name of four Roman emperors.

I. M. CLODIUS PUPIENUS MAXIMUS, joint emperor with D. Caelius Calvinus Balbinus during a few months of the year A.D. 238. Pupienus was a distinguished soldier, who had been proconsul of Bithynia, Achaea, and Gallia Narbonensis. At the advanced age of 74, he was chosen by the senate with Balbinus to resist the barbarian Maximinus. It was arranged that Pupienus should take the field against Maximinus, while Balbinus remained at Rome to maintain order. On his march, Pupienus, having received the news that Maximinus had been assassinated by his own troops, returned in triumph to Rome. Shortly afterwards, when both emperors were on the point of leaving the city on an expedition—Pupienus against the Persians and Balbinus against the Goths—the praetorians, who cherished the memory of the soldier-emperor Maximinus, seized the opportunity of revenge When most of the people were at the Capitoline games, they forced their way into the palace and put Balbinus and Pupienus

to death.

See Capitolinus, *Lives of Maximus and Balbinus;* Herodian vii. 10, viii. 6; Zonaras xii. 16; Zosimus i. 14; Aurelius Victor, *Caesares*, 26, *epit.* 26; Gibbon, *Decline and Fall*, ch. 7 and (for the chronology) appendix 12 (Bury's edition); Stuart Jones, *Roman Empire;* A. Stein in *Realencyklopädie* 4, 888–898, 3, 1258–1265.

II. Magnus Maximus, a native of Spain, who had accompanied Theodosius on several expeditions, and from 368 seems to have had some office in Britain, where he was proclaimed emperor by the disaffected troops. Denuding, as it would seem, Hadrian's Wall of its garrison, he crossed over to Gaul, and overthrew Gratian. Theodosius being unable to avenge the death of his colleague, an agreement was made (384 or 385) by which Maximus was recognized as Augustus and sole emperor in Gaul, Spain and Britain, while Valentinian II. was to rule Italy and Illyricum. In 387 Maximus crossed the Alps and Valentinian was forced to fly to Theodosius. Theodosius now took vigorous measures. Advancing with a powerful army he defeated the troops of Maximus—at Siscia on the Save, and at Poetovio on the Danube. He then hurried on to Aquileia, where Maximus had shut himself up, and had him beheaded.

Full account with classical references in H. Richter, *Das weströmische Reich, besonders unter den Kaisern Gratian, Valentinian II. und Maximus* (1865); Gibbon, *Decline and Fall*, ch. 27; Tillemont, *Hist. des empereurs*, v.; A. Bauer, *Chronologie des Maximus* (1905); Collingwood, in *J.R.S.* 13, p. 74 *et seq.*

III. Maximus Tyrannus, made emperor in Spain by the Roman general, Gerontius, who had rebelled against the usurper Constantine in 408. After the defeat of Gerontius at Arelate (Arles) and his death in 411 Maximus renounced the imperial title and was permitted by Constantine to retire into private life. About 418 he rebelled again, but, failing in his attempt, was seized, carried into Italy, and put to death at Ravenna in 422.

See Orosius vii. 42; Zosimus vi. 5; E. A. Freeman, "The Tyrants of Britain, Gaul and Spain, A.D. 406–411," in *English Historical Review*, i. (1886).

IV. Petronius Maximus, a member of the higher Roman nobility, had held several court and public offices. He was one of the intimate associates of Valentinian III., but an outrage committed on the wife of Maximus by the emperor turned his friendship into hatred. Maximus was proclaimed emperor immediately after Valentinian's murder (March 16, 455), but after reigning less than three months, he was murdered by some Burgundian mercenaries as he was fleeing before the troops of Gaiseric who had landed at the mouth of the Tiber (May or June 455).

See Procopius, *Vand.* i. 4; Sidonius Apollinaris, *Panegyr. Aviti*, ep. ii. 13; Gibbon, *Decline and Fall*, chs. 35, 36; *Chronica Minda*, vols. 1, 2 and 3, Ed. Mommsen; Tillemont, *Hist. des empereurs*, vi.

MAXIMUS OF SMYRNA (*fl.* 4th cent. A.D.), a Greek philosopher of the Neoplatonist school, was perhaps the most important of the followers of Iamblichus. He is said to have exercised great influence over the emperor Julian, to whose love of magic and theurgy he pandered. His overbearing manner made him numerous enemies, and, after being imprisoned on the death of Julian, he was put to death by Valens. He represents the least attractive side of Neoplatonism, enlarging on the wonders and mysteries of nature, and working miracles.

MAXWELL, the name of a Scottish family, members of which have held the titles of earl of Morton, earl of Nithsdale, Lord Maxwell, and Lord Herries. The name is taken probably from Maccuswell, or Maxwell, near Kelso, whither the family migrated from England *c.* 1100. Sir Herbert Maxwell won fame by defending his castle of Carlaverock against Edward I. in 1300; another Sir Herbert was made a lord of the Scottish parliament before 1445; and his great-grandson John, 3rd Lord Maxwell, was killed at Flodden in 1513. John's son Robert, the 4th lord (d. 1546), was a member of the royal council under James V.; he was also an extraordinary lord of session, high admiral, and warden of the west marches, and was taken prisoner by the English at the rout of Solway Moss in 1542. Robert's grandson John, 7th Lord Maxwell (1553–93), was the second son of Robert, the 5th lord (d. 1552), and his wife Beatrix, daughter of James Douglas, 3rd earl of Morton. After the execution of the regent Morton, the 4th earl, in 1581 this earldom was bestowed upon Maxwell, but in 1586 the attainder of the late earl was reversed and he was deprived of his new title. He had helped in 1585 to drive the royal favourite James Stewart, earl of Arran, from power, and he made preparations to assist the invading Spaniards in 1588. His son John, the 8th lord (*c.* 1586–1613), after a life of lawlessness escaped from Scotland and was sentenced to death; having returned he was seized and beheaded in Edinburgh. In 1618 John's brother and heir Robert (d. 1646) was restored to the lordship of Maxwell, and in 1620 was created earl of Nithsdale, surrendering at this time the claim to the earldom of Morton. He and his son Robert, afterwards the 2nd earl, fought under Montrose for Charles I. during the Civil War. Robert died without sons in Oct. 1667, when a cousin John Maxwell, 7th Lord Herries (d. 1677), became third earl.

William, 5th earl of Nithsdale (1676–1744), a grandson of the third earl, joined the Jacobite insurgents in 1715, was taken prisoner at the battle of Preston and sentenced to death. He escaped from the Tower of London, was attainted in 1716 and his titles became extinct, but his estates passed to his son William (d. 1776), whose descendant, William Constable-Maxwell, regained the title of Lord Herries in 1858.

MAXWELL, ANNA CAROLINE (1851–1929), American nurse administrator, was born in Bristol, N.Y., on March 14, 1851. She graduated at the Boston City hospital, Boston, and held the position of director of nursing in Montreal, Boston and New York hospitals before establishing the school of nursing at the Presbyterian hospital in New York, 1892. During the 30 years she was head of it she gave it an excellent reputation. The nurses' residence of the new Presbyterian medical centre, New York, opened in 1928, was named the "Anna C. Maxwell hall" in her honour. For her services as head of the Presbyterian hospital unit overseas during the World War she was decorated by France. In the Spanish War of 1898 the U.S. Government appointed her director of nursing at Chickamauga. Under her leadership the scourge of disease among the soldiers was controlled. With Amy Elizabeth Pope she wrote *Practical Nursing* (1914; Spanish transl., 1919). She died at New York city on Jan. 2, 1929.

MAXWELL, JAMES CLERK (1831–1879), British physicist, was descended from the well-known Scottish family of Clerk of Penicuik, and was born at Edinburgh on Nov. 13, 1831. He was educated at the Edinburgh academy (1840–47), the University of Edinburgh (1847–50), and at Cambridge. In 1854 he took his degree as second wrangler, and shared with the senior wrangler of his year (E. J. Routh, *q.v.*) the Smith's prize. He held the chair of natural philosophy in Marischal college, Aberdeen (1856–60), and the chair of physics and astronomy in King's college, London (1860–68). He resigned and retired to his estate of Glenlair in Kirkcudbrightshire. He was summoned from his seclusion in 1871 to become the first holder of the newly founded professorship of experimental physics in Cambridge; and it was under his direction that the plans of the Cavendish laboratory were prepared. He died at Cambridge on Nov. 5, 1879.

For more than half of his brief life he held a prominent position in the very foremost rank of natural philosophers. His contributions to scientific societies began in his 15th year, when Professor J. D. Forbes communicated to the Royal Society of Edinburgh a short paper of his on a mechanical method of tracing Cartesian ovals. In his 18th year, while still a student in Edinburgh, he contributed two valuable papers to the *Transactions* of the same society—one of which, "On the Equilibrium of Elastic Solids," is remarkable, not only on account of its intrinsic power and the youth of its author, but also because in it he laid the foundation of one of the most singular discoveries of his later life, the temporary double refraction produced in viscous liquids by shearing stress. Immediately after taking his degree, he read to the Cambridge Philosophical Society a very novel memoir, "On the Transformation of Surfaces by Bending." This is one of the few purely mathematical papers he published, and it exhibited at once to experts the full genius of its author.

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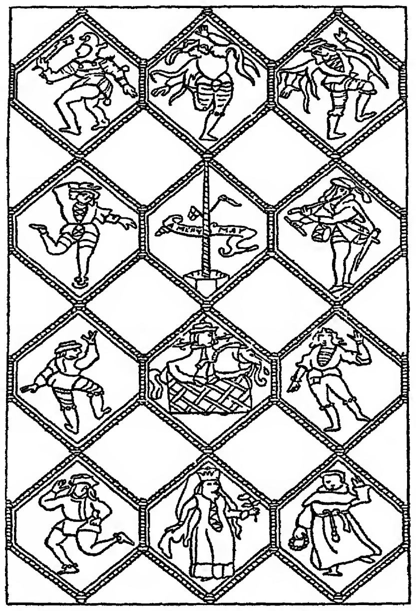

FROM C. COX, "CHURCHWARDENS' ACCOUNTS"

OLD ENGLISH MAY-DAY REVELS

This drawing of a window in Betley Hall, Staffordshire, erected in the time of Edward IV., shows the earliest known picture of a maypole

May day was selected as an international Labour holiday by the International Socialist Congress of 1889. (*See* LABOUR DAY.)

For an account of the May day survivals in rural England *see* John Brand, *Popular Antiquities of Great Britain* (1905).

MAY, ISLE OF, an island of Fifeshire, Scotland, at the entrance to the Firth of Forth, 5 m. S E of Crail and Anstruther. It is more than 1 m. long, and measures at its widest about one-third m. St. Adrian settled here and was martyred by the Danes in the 9th century. The ruins exist of the small chapel dedicated to him, which was a favourite place of pilgrimage. The place where the pilgrims—of whom James IV. was often one—landed is still known as Pilgrims' Haven, and traces may be seen of the various holy wells, now brackish.

MAYA, an important tribe and stock of American Indians, the dominant race of Yucatan and other states of Mexico and part of Central America at the time of the Spanish conquest. They were then divided into many nations, chief among them being the Maya proper, the Huastecs, the Tzental, the Pokom, the Mame and the Cakchiquel and Quiché They were spread over Yucatan, Vera Cruz, Tabasco, Campeche, and Chiapas in Mexico, and over the greater part of Guatemala and Salvador. Their traditions give as their place of origin the extreme north; thence they migrated some time before the beginning of the Christian era and reached Yucatan as early as the 5th century. Physically the Mayans are a dark-skinned, round-headed, short and sturdy type. They still form the bulk of the inhabitants of Yucatan. For their culture, ruined cities, etc., *see* CENTRAL AMERICA and MEXICO.

MAYAGÜEZ, a city on the west coast of Porto Rico. Its population by the census of 1930 was 37,060, while the population of the municipal district was 58,270. The population of the city in 1935 probably exceeded 40,000. Mayagüez was founded in 1763, but was under the jurisdiction of San Germán. In 1836 its separation was authorized by royal decree from Madrid. It has a commodious harbour, and considerable shipping is done both of exports and imports. It is connected with other cities of the island by the American railroad, and by first class highways with motor-bus service. It has a street railway, water-works, electric light and power, a public library, fire department, public market and well-paved streets. The city has developed within recent years an important manufacturing and industrial interest in the production of clothing for the markets in the States, principally of cotton of the cheaper grades The garments are produced in manufacturing establishments employing hundreds of workers and is also carried on by piece-work in the homes of the people. This development has given employment to thousands of workers, and the wages distributed have greatly increased the prosperity and growth of the city as a commercial centre.

Mayagüez has an excellent system of public schools and is the seat of the College of Agriculture and the Mechanic Arts of the University of Porto Rico. A Federal experiment station, under the U S. department of agriculture, is situated here. The Reform School for Boys is also here.

The principal agricultural products of the district are sugar-cane, coffee, tobacco, bananas and tropical fruits. (H. M. T.)

MAY APPLE (*Podophyllum peltatum*), a North American plant of the barberry family (Berberidaceae), called also American mandrake, native to low woods from Quebec to Manitoba and southward to Florida and Texas. It is an erect, perennial herb, 12 in. to 18 in. high, which springs from a horizontal rootstock. The stem bears two large, shield-shaped, deeply lobed leaves, sometimes nearly a foot in diameter, in the axil between which rises in May a single stout-stalked, fragrant, white flower, about 2 in. broad, with six or more petals. The fruit, which ripens in July, is an oval, fleshy, yellow, edible berry about 2 in. long. In many districts the may apple is an abundant and conspicuous spring wild flower and has received numerous local names. Its poisonous rootstalk yields the powerful drug podophyllin (*q.v.*).

MAYBOLE, burgh of barony in Ayrshire, Scotland, 9 m. S. of Ayr and 50½ m. S.W. of Glasgow by L.M.S.R. Pop. (1931) 4,210. It received a charter from Duncan II. in 1193, and was made a burgh of regality in 1516, but for generations it remained under the subjection of the Kennedys, afterwards earls of Cassillis and marquesses of Ailsa, the most powerful family in Ayrshire. Maybole was once the capital of the district of Carrick, and the castle of the earls of Cassillis remains. The leading manufactures are of boots and shoes and agricultural implements.

MAYEN, a town of Germany, in the Prussian Rhine province, on the northern slope of the Eifel range, 16 m. W. from Coblenz, on the railway Andernach-Gerolstein. Pop. (1933) 15,515. Mayen was a Roman settlement and became a town in 1291. It is still partly surrounded by mediaeval walls, and the ruins of a castle rise above the town There are some small industries.

MAYENNE, CHARLES OF LORRAINE, DUKE OF (1554–1611), second son of Francis of Lorraine, second duke of Guise, was born on March 26, 1554. He was absent from France at the time of the massacre of Saint Bartholomew, but took part in the siege of La Rochelle in the following year, when he was created duke and peer of France. He went with Henry of Valois, duke of Anjou (afterwards Henry III.), on his election as king of Poland. On his return to France he fought under his brother, the 3rd duke of Guise, against the Huguenots. As governor of Burgundy he raised his province in the cause of the League in 1585. The assassination of his brothers at Blois on Dec. 23 and 24, 1588 left him at the head of the Catholic party. The Venetian ambassador, Mocenigo, states that Mayenne had warned Henry III. that there was a plot afoot to seize his person and to send him

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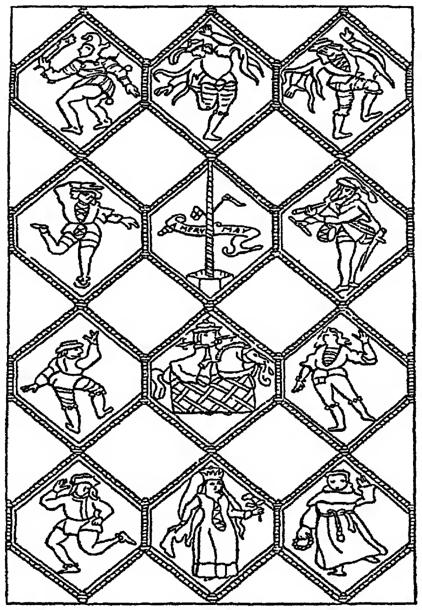
MAY, the fifth month of our modern year, the third of the old Roman calendar perhaps derived from the name of the goddess Maia. The ancient Romans used on May day to go in procession to the grotto of Egeria. (May day was in the middle of the Floralia.) The month was regarded as unlucky for marriages, owing to the celebration of the Lemuria, the festival of the unhappy dead.

In mediaeval and Tudor England, May day was a great public holiday. All classes of the people were up with the dawn, and went "a-maying." Branches of trees and flowers were borne back in triumph to the towns and villages, the centre of the procession being occupied by the maypole, glorious with ribbons and wreaths. The maypole was usually of birch, and set up for the day only; but in London and the larger towns the poles were of durable wood and permanently erected. They were special eyesores to the Puritans. Maypoles were forbidden by the parliament in 1644, but came once more into favour at the Restoration. In 1661 a maypole 134ft. high was set up by twelve British sailors under the personal supervision of James II., then Duke of York and lord high admiral, in the Strand.



FROM C. COX, "CHURCHWARDENS' ACCOUNTS"

OLD ENGLISH MAY-DAY REVELS

This drawing of a window in Betley Hall, Staffordshire, erected in the time of Edward IV., shows the earliest known picture of a maypole

May day was selected as an international Labour holiday by the International Socialist Congress of 1889. (*See* LABOUR DAY.)

For an account of the May day survivals in rural England *see* John Brand, *Popular Antiquities of Great Britain* (1905).

MAY, ISLE OF, an island of Fifeshire, Scotland, at the entrance to the Firth of Forth, 5 m. S.E of Crail and Anstruther. It is more than 1 m. long, and measures at its widest about one-third m. St. Adrian settled here and was martyred by the Danes in the 9th century. The ruins exist of the small chapel dedicated to him, which was a favourite place of pilgrimage. The place where the pilgrims—of whom James IV. was often one—landed is still known as Pilgrims' Haven, and traces may be seen of the various holy wells, now brackish.

MAYA, an important tribe and stock of American Indians, the dominant race of Yucatan and other states of Mexico and part of Central America at the time of the Spanish conquest. They were then divided into many nations, chief among them being the Maya proper, the Huastecs, the Tzental, the Pokom, the Mame and the Cakchiquel and Quiché. They were spread over Yucatan, Vera Cruz, Tabasco, Campeche, and Chiapas in Mexico, and over the greater part of Guatemala and Salvador. Their traditions give as their place of origin the extreme north; thence they migrated some time before the beginning of the Christian era and reached Yucatan as early as the 5th century. Physically the Mayans are a dark-skinned, round-headed, short and sturdy type. They still form the bulk of the inhabitants of Yucatan. For their culture, ruined cities, etc., *see* CENTRAL AMERICA and MEXICO.

MAYAGÜEZ, a city on the west coast of Porto Rico. Its population by the census of 1930 was 37,060, while the population of the municipal district was 58,270. The population of the city in 1935 probably exceeded 40,000. Mayagüez was founded in 1763, but was under the jurisdiction of San Germán. In 1836 its separation was authorized by royal decree from Madrid. It has a commodious harbour, and considerable shipping is done both of exports and imports. It is connected with other cities of the island by the American railroad, and by first class highways with motor-bus service. It has a street railway, water-works, electric light and power, a public library, fire department, public market and well-paved streets. The city has developed within recent years an important manufacturing and industrial interest in the production of clothing for the markets in the States, principally of cotton of the cheaper grades. The garments are produced in manufacturing establishments employing hundreds of workers and is also carried on by piece-work in the homes of the people. This development has given employment to thousands of workers, and the wages distributed have greatly increased the prosperity and growth of the city as a commercial centre.

Mayagüez has an excellent system of public schools and is the seat of the College of Agriculture and the Mechanic Arts of the University of Porto Rico. A Federal experiment station, under the U S. department of agriculture, is situated here. The Reform School for Boys is also here.

The principal agricultural products of the district are sugar-cane, coffee, tobacco, bananas and tropical fruits. (H. M. T.)

MAY APPLE (*Podophyllum peltatum*), a North American plant of the barberry family (Berberidaceae), called also American mandrake, native to low woods from Quebec to Manitoba and southward to Florida and Texas. It is an erect, perennial herb, 12 in. to 18 in. high, which springs from a horizontal rootstock. The stem bears two large, shield-shaped, deeply lobed leaves, sometimes nearly a foot in diameter, in the axil between which rises in May a single stout-stalked, fragrant, white flower, about 2 in. broad, with six or more petals. The fruit, which ripens in July, is an oval, fleshy, yellow, edible berry about 2 in. long. In many districts the may apple is an abundant and conspicuous spring wild flower and has received numerous local names. Its poisonous rootstalk yields the powerful drug podophyllin (*q.v.*).

MAYBOLE, burgh of barony in Ayrshire, Scotland, 9 m. S. of Ayr and 50¼ m. S.W. of Glasgow by L.M.S.R. Pop. (1931) 4,210. It received a charter from Duncan II. in 1193, and was made a burgh of regality in 1516, but for generations it remained under the subjection of the Kennedys, afterwards earls of Cassillis and marquesses of Ailsa, the most powerful family in Ayrshire. Maybole was once the capital of the district of Carrick, and the castle of the earls of Cassillis remains. The leading manufactures are of boots and shoes and agricultural implements.

MAYEN, a town of Germany, in the Prussian Rhine province, on the northern slope of the Eifel range, 16 m. W. from Coblenz, on the railway Andernach-Gerolstein. Pop. (1933) 15,515. Mayen was a Roman settlement and became a town in 1291. It is still partly surrounded by mediaeval walls, and the ruins of a castle rise above the town. There are some small industries.

MAYENNE, CHARLES OF LORRAINE, DUKE OF (1554–1611), second son of Francis of Lorraine, second duke of Guise, was born on March 26, 1554. He was absent from France at the time of the massacre of Saint Bartholomew, but took part in the siege of La Rochelle in the following year, when he was created duke and peer of France. He went with Henry of Valois, duke of Anjou (afterwards Henry III.), on his election as king of Poland. On his return to France he fought under his brother, the 3rd duke of Guise, against the Huguenots. As governor of Burgundy he raised his province in the cause of the League in 1585. The assassination of his brothers at Blois on Dec. 23 and 24, 1588 left him at the head of the Catholic party. The Venetian ambassador, Mocenigo, states that Mayenne had warned Henry III. that there was a plot afoot to seize his person and to send him

by force to Paris. At the time of the murder he was at Lyons, where he received a letter from the king saying that he had acted on his warning, and ordering him to retire to his government.

Mayenne professed obedience, but immediately made preparations for marching on Paris. After a vain attempt to release his relatives who had been arrested at Blois, he recruited troops in his government of Burgundy and in Champagne. When Mayenne entered Paris (Feb. 1589) he formed a council general to direct the affairs of the city and to maintain relations with the other towns faithful to the League. To this council each quarter sent four representatives, and Mayenne added representatives of the various trades and professions of Paris in order to counterbalance this revolutionary element. He constituted himself "lieutenant-general of the State and crown of France," taking his oath before the parlement of Paris. In April he advanced on Tours. Henry III. in his extremity sought an alliance with Henry of Navarre, and the allied forces drove the leaguers back, and had laid siege to Paris, when the murder of Henry III. by a Dominican fanatic changed the face of affairs and gave new strength to the Catholic party.

Mayenne was urged to claim the crown for himself, but he proclaimed Charles, cardinal of Bourbon, at that time a prisoner in the hands of Henry IV., as Charles X. Henry IV. retired to Dieppe, followed by Mayenne, who joined his forces with those of his cousin Charles, duke of Aumale, and Charles de Cossé, comte de Brissac, and engaged the royal forces in a succession of fights in the neighbourhood of Arques (September 1589) He was defeated and out-marched by Henry IV., who moved on Paris, but retreated before Mayenne's forces. In 1590 Mayenne received additions to his army from the Spanish Netherlands, and took the field again, only to suffer complete defeat at Ivry (March 14, 1590). He then escaped to Mantes, and in September collected a fresh army at Meaux, and with the assistance of Alexander Farnese, prince of Parma, sent by Philip II., raised the siege of Paris, which was about to surrender to Henry IV. Mayenne feared with reason the designs of Philip II., and his difficulties were increased by the death of Charles X., the "king of the league." The extreme section of the party, represented by the Sixteen, urged him to proceed to the election of a Catholic king and to accept the help and the claims of their Spanish allies.

But Mayenne, who had not the popular gifts of his brother, the duke of Guise, had no sympathy with the demagogues, and himself inclined to the moderate side of his party, which began to urge reconciliation with Henry IV. He maintained the ancient forms of the constitution against the revolutionary policy of the Sixteen, who during his absence from Paris took the law into their own hands and in November 1591 executed one of the leaders of the more moderate party, Barnabé Brisson, president of the parlement. He returned to Paris and executed four of the chief malcontents. The power of the Sixteen diminished from that time, but with it the strength of the League.

Mayenne entered into negotiations with Henry IV. while he was still appearing to consider with Philip II. the succession to the French crown of the Infanta Elizabeth, granddaughter, through her mother Elizabeth of Valois, of Henry II. He demanded that Henry IV. should accomplish his conversion to Catholicism before he was recognized by the leaguers. He also desired the continuation to himself of the high offices which had accumulated in his family and the reservation of their provinces to his relatives among the leaguers. In 1593 he summoned the States General to Paris and placed before them the claims of the Infanta, but they protested against foreign intervention. Mayenne signed a truce at La Villette on July 31, 1593. The internal dissensions of the league continued to increase, and the principal chiefs submitted. Mayenne finally made his peace only in Oct. 1595. Henry IV. allowed him the possession of Chalon-sur-Saône, of Seurre and Soissons for three years, made him governor of the Isle of France and paid a large indemnity. Mayenne died at Soissons on Oct. 3, 1611.

See the literature dealing with the house of Guise (*q.v.*).

MAYENNE, a department of north-western France, bounded on the north by Manche and Orne, east by Sarthe, south by Maine-et-Loire and west by Ille-et-Vilaine. Area, 1,986 sq. miles. Pop. (1931) 254,479. The department forms the eastern portion of the Armorican system of Palaeozoic rocks, with zones of granite running east and west in its northern part. The Mayenne cuts across the grain of the country in its course from north to south through the middle of the department; it receives a number of small tributaries. The Oudon runs parallel to it in the south of the department and then turns eastward to join it in the department of Maine-et-Loire. The land in the north-east rises to 1,368 feet. Varying zones of soil give sandy heaths alternating with marshes that make the air moist and foggy; the rainfall is rather above the average (32 in.) and the temperature is slightly lower than in neighbouring departments.

Large numbers of horned cattle and horses are reared, and the Craon breeds of horses and pigs are famous. Mayenne produces butter and poultry and much honey. The cultivation of the vine is very limited, and the most common beverage is cider. Wheat, barley, oats and buckwheat are the most important crops, and much flax and hemp is produced. Game is abundant. The timber grown is chiefly beech, oak, birch, elm and chestnut. The department produces vanadium, antimony, auriferous quartz and coal Marble, slate and other stone are quarried. There are several chalybeate springs. Exports include agricultural produce, live-stock, timber and stone. The department is served by the Ouest-État railway. It forms part of the circumscriptions of the IV army corps, the académie (educational division) of Rennes, and the court of appeal of Angers. It comprises three arrondissements (Laval, Château-Gontier and Mayenne), with 27 cantons and 276 communes. Laval, the capital, is the seat of a bishopric of the province of Tours. The other principal towns are Château-Gontier and Mayenne. The following places are also of interest: Evron, which has a church of the 12th and 13th centuries; Jublains, with a Roman fort and other Roman remains; Lassay, with a fine château of the 14th and 16th centuries; and Ste. Suzanne, which has remains of mediaeval ramparts and a fortress with a Romanesque keep.

MAYENNE, a town of north-western France, capital of an arrondissement in the department of Mayenne, 19 m. N.N.E of Laval by rail. Pop. (1931) 5,084. Mayenne had its origin in the castle built here by Juhel, baron of Mayenne, the son of Geoffrey of Maine, in the beginning of the 11th century. It was taken by William the Conqueror in 1068, and again after a three months' siege in 1424. It was captured several times by the opposing parties in the wars of religion and of the Vendée. At the beginning of the 16th century the territory passed to the family of Guise, and in 1573 was made a duchy in favour of Charles of Mayenne, leader of the league. Mayenne is an old feudal town, irregularly built on hills on both sides of the river Mayenne. Of the old castle overlooking the river several towers remain, also the vaulted chambers and a 13th century chapel; the building is now used as a prison. The Gothic church of Notre-Dame dates partly from the 12th century; the choir was rebuilt in the 19th century. Mayenne has a subprefecture, tribunals of first instance and of commerce, a chamber of arts and manufactures, and a board of trade-arbitration. The chief industry of the place is the manufacture of tickings, linen, handkerchiefs and calicoes.

MAYER, JOHANN TOBIAS (1723–1762), German astronomer, was born at Marbach, in Württemberg, on Feb. 17, 1723, and brought up at Esslingen. A self-taught mathematician, he had already published two original geometrical works when, in 1746, he entered J. B. Homann's cartographic establishment at Nuremberg. Here he introduced many improvements in map-making, and gained a scientific reputation which led (in 1751) to his election to the chair of economy and mathematics in the university of Göttingen. In 1754 he became superintendent of the observatory, where he laboured with great zeal and success until his death, on Feb. 20, 1762. His first important astronomical work was a careful investigation of the libration of the moon (*Kosmographische Nachrichten*, Nuremberg, 1750), and his chart of the full moon (published in 1775) was unsurpassed for half a century. But his fame rests chiefly on his lunar tables, communicated in 1752, with new solar tables, to the Royal Society of Göttingen,

and published in their *Transactions* (vol. ii.). In 1755 he submitted to the English government an amended body of MS. tables, which Bradley found to be sufficiently accurate to determine the moon's place to 75″, and consequently the longitude at sea to about half a degree. An improved set was afterwards published in London (1770), as also the theory (*Theoria lunae juxta systema Newtonianum,* 1767) upon which the tables are based. His widow received in consideration from the British government a grant of £3,000. Appended to the London edition of the solar and lunar tables are two short tracts—the one on determining longitude by lunar distances, together with a description of the repeating circle (invented by Mayer in 1752), the other on a formula for atmospheric refraction, which applies a remarkably accurate correction for temperature.

Part of Mayer's manuscript was collected by G. C. Lichtenberg (*Opera inedita,* Göttingen, 1775). It contains an easy and accurate method for calculating eclipses; an essay on colour; a catalogue of 998 zodiacal stars; and a memoir, the earliest of any real value, on the proper motion of eighty stars, originally communicated to the Göttingen Royal Society in 1760. In an unpublished manuscript Mayer sought to explain the magnetic action of the earth by a modification of Euler's hypothesis, and made the first really definite attempt to establish a mathematical theory of magnetic action (C. Hansteen, *Magnetismus der Erde,* i. 283). E. Klinkerfuss published in 1881 photo-lithographic reproductions of Mayer's local charts and general map of the moon; and his star-catalogue was re-edited by F. Baily in 1830 (*Memoirs Roy. Astr. Soc.* iv. 391) and by G. F. J. A. Auvers in 1894.

See A. G. Kästner, *Elogium Tobiae Mayeri* (Göttingen, 1762).

(A. M. C.; X.)

MAYER, JULIUS ROBERT (1814–1878), German physicist, was born at Heilbronn on Nov. 25, 1814, studied medicine at Tübingen, Munich and Paris, and after a journey to Java in 1840 as surgeon of a Dutch vessel obtained a medical post in his native town. He claims recognition as an independent a priori propounder of the "First Law of Thermodynamics," but more especially as having early and ably applied that law to the explanation of many remarkable phenomena, both cosmical and terrestrial. His first paper on the subject, "Bemerkungen über die Kräfte der unbelebten Natur," appeared in 1842 in Liebig's *Annalen,* and three years later he published *Die organische Bewegung in ihrem Zusammenhange mit dem Stoffwechsel.* There was a good deal of controversy regarding the priority of Mayer's ideas; this, together with the lack of appreciation accorded to his work, and domestic grief, affected Mayer's mind. In 1851 he was placed in an asylum and, although he was released, his mind never completely recovered. He died at Heilbronn on March 20, 1878. His papers were republished in a single volume with the title *Die Mechanik der Wärme* (1893).

Different, and it would appear exaggerated, estimates of Mayer are given in John Tyndall's papers in the *Phil. Mag.,* 1863–64 and in E. Dühring's *Robert Mayer, der Galilei des neunzehnten Jahrhunderts,* Chemnitz, 1880. Some of the simpler facts of the case are summarized by Tait in the *Phil. Mag.,* 1864.

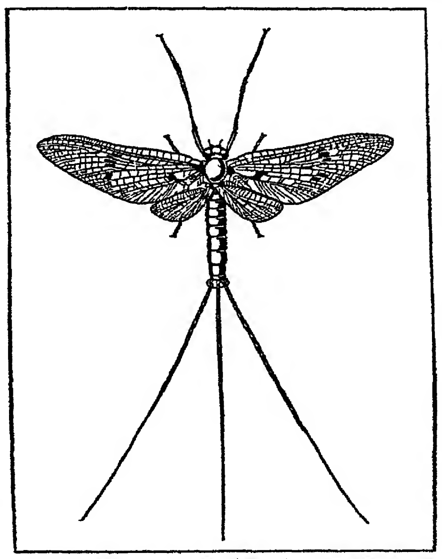
MAYFIELD, a city of south-western Kentucky, U.S.A., the county seat of Graves county; on Federal highway 45 and the Illinois Central railroad. Pop. (1920) 6,583; 8,177 in 1930. It is the trade centre of a rich farming region, raising chiefly tobacco, grain and poultry, and has a variety of manufacturing industries. The city was founded in 1811 and incorporated in 1823.

MAYFLOWER, the vessel which carried from Southampton, England, to Plymouth, Mass., the Pilgrims who established the first permanent colony in New England. It was of about 180 tons burden, and in company with the "Speedwell" sailed from Southampton on Aug. 5, 1620, the two having on board 120 Pilgrims. After two trials the "Speedwell" was pronounced unseaworthy, and the "Mayflower" sailed alone from Plymouth, England, on Sept. 6, with the 100 (or 102) passengers, some 41 of whom on Nov. 11 (O.S.) signed the famous "Mayflower compact" in Provincetown harbour, and a small party of whom, including William Bradford, sent to choose a place for settlement, landed at what is now Plymouth, Mass., on Dec. 11 (21 N.S.), an event which is celebrated, as Forefathers' day, on Dec. 22. A "General Society of Mayflower descendants" was organized in 1894 by lineal descendants of passengers of the "Mayflower" to "preserve their memory, their records, their history, and all facts relating to them, their ancestors and their posterity." Every lineal descendant, over 18 years of age, of any passenger of the "Mayflower" is eligible to membership. Branch societies have since been organized in several of the States and in the District of Columbia, and a triennial congress is held in Plymouth.

See Azel Ames, *The May-Flower and Her Log* (Boston, 1901); Blanche McManus, *The Voyage of the Mayflower* (New York, 1897); *The General Society of Mayflower: Meetings, Officers and Members, arranged in State Societies, Ancestors and their Descendants* (1901); Jas. R. Harris, *The Finding of the Mayflower,* and *The Last of the Mayflower* (Manchester, Eng., 1920); Chas. Banks, *The Officers and Crew of the Mayflower,* Proc. Mass. Hist. Soc., vol. lx., pp. 210–221 (1927). Also the articles PLYMOUTH, Mass.; MASSACHUSETTS: *History;* PILGRIM FATHERS; and PROVINCETOWN, Mass.

MAY-FLY, the name given to those insects formerly classified as the family *Ephemeridae* (Gr. ἐφήμερος, lasting for a day; in allusion to their very short lives) of the old Linnean order Neuroptera. Their very distinctive characters and mode of life have since led entomologists to relegate them to a separate order of their own—the Ephemeroptera or Plectoptera.

May-flies are delicately formed, soft-bodied aërial insects, frequenting the margins of streams, rivers, and lakes. They can be easily recognized by their very short bristle-like antennae, aborted mouth-parts, and net-veined membranous wings, the hind pair being greatly reduced in size. The body is terminated by long thread-like caudal filaments, usually three in number. Their early stages are spent entirely in fresh water; most species lay their eggs in or on the surface of the water, but some descend beneath the water for the purpose, and may die there without reappearing. The eggs adhere together by means of a glutinous covering and are commonly discharged in two masses, but they soon separate in the water and become scattered by the current along the bottom. The nymphs are campodeiform with moderately developed antennae and long caudal filaments: compound eyes and ocellia are usually present; the mouth-parts are well developed and the legs long. Early in life segmentally arranged tracheal gills develop along the sides of the abdomen; in most cases they are leaf-like expansions with tracheal branches ramifying in them. The nymphs moult a number of times, in some cases more than 20 ecdyses occur, and almost the whole life of the insect is spent in this stage. As a rule they are herbivorous, but some species are undoubtedly carnivorous: they are very varied in habit, some kinds frequenting sandy bottoms, others hiding beneath stones, while a certain number burrow in mud or cling to water plants. Some are greatly flattened, and in the remarkable genus *Prosopistoma* the whole body is used as a kind of sucker for attaching the creature to stones in swift running streams: its gills are enclosed in a carapace which forms a branchial chamber, the water entering by a pair of apertures and leaving the chamber by a median exhalant opening. Other forms are active swimmers and live among aquatic vegetation.



BY COURTESY OF THE (BRITISH) MUSEUM OF NATURAL HISTORY

MAY-FLY (EPHEMERA VULGARIS), A WELL-KNOWN FLY OF TROUT STREAMS

When the time for the appearance of the perfect insect arrives the nymph crawls or swims to the surface: a fissure then appears in the dorsal cuticle and the winged insect issues and flies away in a few seconds. At this stage it is known as the sub-imago and it differs from the true imago by its duller appearance, its body and wings being covered by a very delicate pellicle. In this condition the insect soon comes to rest, and after a period varying from a few minutes up to 24 hours or more, the pellicle is finally cast off and the imago or true may-fly emerges with transparent

wings and mature reproductive organs. May-flies are always very short-lived as adults: some species emerge towards evening, pair and lay their eggs, and die before morning: others may live for a few days but they partake of no food during their fugitive life. These insects often issue from the water in great numbers about the same time: some species execute aërial dances consisting of a fluttering swift ascent followed by a more passive and leisurely descent, the two processes being many times repeated. At times their numbers are so great as to darken the air and inconvenience passers-by, especially in Switzerland and Italy.

About 470 species of may-flies are known: they are very widely distributed and about 40 species inhabit the British Isles, but these insects have been very little studied in the tropics and many other parts of the world. In the fossil state true may-flies appear first in Permian rocks and their nymphs are also known from that time. Some of the fossil may-flies are interesting in that the hind wings have undergone little or no reduction in size as occurs in living forms.

The order is to be regarded as beneficial to man: may-flies are eagerly devoured by fishes, while many of the "duns," "spinners," and some of the "drakes," made up by the fly-fisher, represent species of *Ephemera, Palingenia,* or other forms. The nymphs serve as an important source of food for fishes, and in New Zealand the introduced trout has lessened their numbers so much that some of the native may-flies are becoming extremely scarce.

The standard work on these insects is A. E. Eaton's monograph, *Trans. Linnean Soc.* (2) iii. (1883–85), which figures many species and their nymphs. *See* also L. C. Miall, *Natural History of Aquatic Insects* (1913); J. G. Needham in Ward and Whipples' *Freshwater Biology* (1918); and in *Bull. 86 New York State Museum* (1905); F. Klapalek in Brauer's *Susswasserfauna Deutschlands* pt. 8 (Jena, 1909), and E. Rousseau, *Les Larves et Nymphes Aquatiques* (Bruxelles, 1921). (A. D. I.)

MAYHEM, an old Anglo-French term of the law signifying an assault whereby the injured person is deprived of a member proper for his defence in fight, *e.g.,* an arm, a leg, a fore tooth, etc. The loss of an ear, jaw tooth, etc. was not mayhem. The most ancient punishment in English law was retaliative—*membrum pro membro,* but ultimately at common law fine and imprisonment. Various statutes were passed aimed at the offence of maiming and disfiguring, which is now dealt with by s. 18 of the Offences against the Person Act, 1861. Mayhem may also be the ground of a civil action.

In the United States, mayhem has been extended by statute to include "maim," which means to mutilate. It is punishable both as a felony and misdemeanour and also may be the ground for civil action.

MAYHEW, HENRY (1812–1887), English author and journalist, son of a London solicitor, was one of the leading spirits in the foundation of *Punch,* of which he was for the first two years joint-editor with Mark Lemon. He began his journalistic career by founding, with Gilbert à Beckett, in 1831, a weekly paper, *Figaro in London.* This was followed in 1832 by a short-lived paper called *The Thief;* and he produced one or two successful farces. His brothers Horace (1816–72) and Augustus Septimus (1826–75) were also journalists, and with them Henry occasionally collaborated. He is credited with being the first to "write up" the poverty side of London life from a philanthropic point of view; with the collaboration of John Binny and others he published *London Labour and London Poor* (1851; completed 1864) and other works on social and economic questions. He died in London on July 25, 1887.

MAYHEW, THOMAS, English 18th century cabinet-maker, was the less distinguished partner of William Ince (*q.v.*). The chief source of information as to his work is the volume of designs, *The universal system of household furniture,* which he published in collaboration with his partner in 1762–3. In the main Mayhew's designs are heavy and clumsy, and often extravagant, but he had a certain lightness of accomplishment in his applications of the bizarre Chinese style, and it is certain that much of his Chinese work has been attributed to Chippendale.

MAYNARD, FRANÇOIS DE (1582–1646), French poet, was born at Toulouse in 1582. His father was *conseiller* in the parlement of the town, and François eventually became president of Aurillac. He was secretary to Margaret of Valois, wife of Henry IV., for whom his early poems are written. He was a disciple of Malherbe, and was one of the earliest members of the Academy. The best of his poems is in imitation of Horace, "Alcippe, reviens dans nos bois." He died at Toulouse on Dec. 23, 1646.

His works consist of odes, epigrams, songs and letters, and were published in 1646 by Marin le Roy de Gomberville.

MAYNE, JASPER (1604–1672), English author, was baptized at Hatherleigh, Devonshire, on Nov. 23, 1604. He wrote a farcical domestic comedy, *The City Match* (1639) and a fantastic tragi-comedy entitled *The Amorous War* (printed 1648). His other works comprise some occasional gems, a translation of Lucian's *Dialogues* (printed 1664) and a number of sermons. He died on Dec. 6, 1672, at Oxford.

MAYNOOTH, a small town of co. Kildare, Ireland, on the Great Southern railway and the Royal canal, 15 m. W. by N. of Dublin. Pop. (1926) 846. The Royal Catholic college of Maynooth, founded in 1795, is the chief seminary for the education of the Roman Catholic clergy of Ireland. The building is a Gothic structure by A. W. Pugin, erected by a parliamentary grant obtained in 1846. The chapel was dedicated in 1890. Near the college stand the ruins of Maynooth castle, probably built in 1176. It was besieged in the reigns of Henry VIII. and Edward VI., and during the Cromwellian Wars, at which time it was demolished.

MAYO, EARLS OF. On the murder of William de Burgh, 3rd earl (*see* BURGH), his male kinsmen became native chieftains and adopted Irish names and customs. Their two main branches were those of "MacWilliam Eighter" in southern Connaught (*see* CLANRICARDE, EARLS OF) and "MacWilliam Oughter" to the north of them, in what is now Mayo.

In 1603 "the MacWilliam Oughter," Theobald Bourke, resigned his territory in Mayo, and received it back to hold by English tenure. In 1627 he was created Viscount Mayo. The 2nd and 3rd viscounts (1629–1663) suffered at Cromwell's hands, but the 4th was restored to his estates (some 50,000 ac.) in 1666. The peerage became extinct or dormant on the death of the 8th viscount in 1767. In 1781 John Bourke, a Mayo man, believed to be descended from the line of "MacWilliam Oughter," was created Viscount Mayo, and four years later earl of Mayo, a peerage still extant.

MAYO, CHARLES HORACE (1865–), American surgeon, was born at Rochester, Minn., on July 19, 1865. After studying at the Rochester high school, private schools, Northwestern university and the Chicago Medical college he began the practice of surgery at Rochester, Minn., and with his brother and father founded the Mayo Clinic. His methods have had a strong influence in moulding the practice of surgery in its various departments as these have evolved with the growth of the institution. In addition to goitre, urologic and general surgery, all of which he is still practising, his early work included operations on the eye, ear, nose and throat, and neurologic, orthopedic, thoracic and plastic surgery. He made a special study of goitre and as a result succeeded in reducing the death rate in this class of cases by half. Outside of surgery, his chief interest is in focal infection and preventive medicine. He has published many papers covering a wide range of subjects, mostly surgical. He is a charter member of the American College of Surgeons. He was awarded the Distinguished Service Medal, U.S. Army, in 1920, and commissioned brigadier general M.O.R.C. in 1921.

Beginning with 1912, graduate courses in medicine were offered at the Mayo Clinic in Rochester. Early in 1915, Charles Mayo and his brother founded The Mayo Foundation for Medical Education and Research at Rochester, and to it the brothers gave $1,500,000. By mutual agreement, the funds and resources of the foundation were placed under the direction of the regents of the University of Minnesota for promoting "graduate work in medicine and research" and the foundation became a department of the Graduate school of the University of Minnesota. (*See* SURGERY; MINNESOTA, UNIVERSITY OF.)

MAYO, RICHARD SOUTHWELL BOURKE, 6th Earl of (1822–1872), British statesman, son of Robert Bourke, the 5th earl (1797–1867), was born in Dublin on Feb. 21, 1822, and was educated at Trinity College, Dublin. He was chief secretary for Ireland in three administrations, in 1852, 1858 and 1866, and was appointed viceroy of India in 1869. He consolidated the frontiers of India and met Shere Ali, amir of Afghanistan, in durbar at Umballa in March 1869. His reorganization of the finances of the country put India on a paying basis; and he did much to promote irrigation, railways, forests and other public works. Visiting the convict settlement at Port Blair in the Andaman Islands, for the purpose of inspection, the viceroy was assassinated by a convict on Feb. 8, 1872.

See Sir W. W. Hunter, *Life of the Earl of Mayo* (1876), and *The Earl of Mayo* in the Rulers of India Series (1891).

MAYO, WILLIAM JAMES (1861–), American surgeon. was born at Le Sueur, Minn., June 29, 1861. He graduated from the University of Michigan (M.D. 1883), and from the University of Dublin (Trinity college) (M.D. in surgery, 1923). Since 1883 he has engaged in the practice of surgery in Rochester, Minn. A small hospital was organized under the local branch of the Sisters of St. Francis, which developed into St. Mary's hospital. Here he, with his younger brother, Charles Horace, developed the Mayo Clinic (organized 1889), which became famous throughout the world for the number and success of operations performed. The records of operations have been so carefully made and preserved that they form a valuable asset to medical science. Dr. W. J. Mayo specialized in the surgery of the stomach, and published a large number of papers on gastric surgery and kindred topics. In 1907 he was appointed a regent of the University of Minnesota. He was elected president of the Minnesota State Medical Society in 1895, of the American Medical Association (1905–06), of the Society for Clinical Surgery in 1911, of the American Surgical Association (1913–14), of the Society of Clinical Surgery (1911–12), of the American college of Surgeons (1917–19) and of the Congress of American Physicians and Surgeons (1925). On America's entrance into the World War he was appointed a colonel in the Medical Corps, U.S. Army, and chief consultant for all surgical service, during the period of the war, alternating with his brother, C. H. Mayo, in this capacity (1917–19). He was a brigadier general, Medical Officers Reserve Corps, U.S. Army, in 1921. *See* Surgery.

MAYO, a western county of Ireland, in the province of Connaught, bounded north and west by the Atlantic Ocean, north-east by Sligo, east by Roscommon, south-east and south by Galway. The area is 1,380,390 acres, or about 2,157 sq.m., the county being the third largest in Ireland. Pop. (1926) 172,661.

The wild and barren west of the county, including the great hills on Achill Island, is formed of "Dalradian" rocks, schists and quartzites, highly folded and metamorphosed, with intrusions of granite near Belmullet. At Blacksod Bay the granite has been quarried as an ornamental stone. Nephin Beg, Nephin (2,646 ft.) and Croagh Patrick (2,510 ft.) are typical quartzite summits, the last named belonging possibly to a Silurian horizon but rising from a metamorphosed area on the south side of Clew Bay. The schists and gneisses of the Ox Mountain axis also enter the county north of Castlebar. Muilrea to the north of the fjord of Killary Harbour, reaches a height of 2,688 ft. To the east of Lough Mask is a Carboniferous Limestone plain. Silurian rocks, with Old Red Sandstone over them, come out at the west end of the Curlew range at Ballaghaderreen. Clew Bay, with its islets capped by glacial drift, is a submerged part of a synclinal of Carboniferous strata, and Old Red Sandstone comes out on the north side of this, from near Achill to Lough Conn. The country from Lough Conn northward to the sea is a lowland of Carboniferous Limestone, with L. Carboniferous Sandstone against the Dalradian on the west.

The coast is much indented, the principal inlets being Killary Harbour between Mayo and Galway; Clew Bay, in which are the harbours of Westport and Newport; Blacksod Bay and Broad Haven, which form the peninsula of the Mullet; and Killala Bay between Mayo and Sligo. The principal islands are Inishturk, near Killary Harbour; Clare Island, at the mouth of Clew Bay where there are many islets, all formed of drift; and Achill, the largest island off Ireland. The river Moy flows northwards, forming part of the boundary of the county with Sligo, and falls into Killala Bay. The principal lakes are Lough Mask and Lough Corrib, on the borders of the county with Galway, and Loughs Conn in the east, Carrowmore in the north-west, Beltra in the west, and Carra adjoining Lough Mask.

Erris in Mayo was the scene of the landing of the chief colony of the Firbolgs, and Moytura near Cong saw their overthrow and almost complete annihilation. At the close of the 12th century what is now the county of Mayo was granted by king John to William, brother of Hubert de Burgh. In the 14th century the land passed to a branch of the family known as "MacWilliam Oughter." Mayo was made shire ground during the first viceroyalty of Sir Henry Sydney, taking its name from the monastery of Maio or Mageo, which was the seat of a bishop. Even after this period the MacWilliams continued to exercise authority, which was regularized in 1603, when "the MacWilliam Oughter," Theobald Bourke, surrendered his lands and received them back, to hold them by English tenure, with the title of Viscount Mayo. (*See* Burgh, De.) Large confiscations were made in 1586, and on the termination of the wars of 1641; and in 1666 the restoration of his estates to the 4th Viscount Mayo involved another confiscation, at the expense of Cromwell's settlers. Killala was the scene of the landing of a French squadron in connection with the rebellion of 1798.

There are round towers at Killala, Turlough, Meelick and Balla, and an imperfect one at Aughagower. Killala was formerly a bishopric. The principal monasteries were those at Mayo, Ballyhaunis, Cong, Ballinrobe, Ballintober, Burrishoole, Cross or Holycross in the peninsula of Mullet, Moyne, Roserk or Rosserick and Templemore or Strade. The most notable old castles are Carrigahooly near Newport, and Deel Castle near Ballina.

The thin soil of the mountains barely supports a scanty population. Conditions are better in the valleys and along the coasts where the fisheries are important. Oats and potatoes are the principal crops. Cattle, sheep, pigs and poultry are reared. Coarse linen and woollen cloths are manufactured to a small extent. At Foxford woollen-mills are established at a nunnery, in connection with a scheme of technical instruction. Keel, Belmullet and Ballycastle are the headquarters of sea and coast fishing districts, and Ballina of a salmon-fishing district.

Claremorris is an important centre on the Great Southern railway. The line from Athlone runs through it and continues north to Ballina and Killala. Similarly it is served by the line from Athenry to Sligo, and has a branch to Ballinrobe. There is a branch from Manulla to Westport and Achill. North Mayo, consisting of the county electoral areas of Ballina, Killala and Swinford, returns 4 members to Dáil Eireann. South Mayo, consisting of the county electoral areas of Castlebar, Claremorris and Westport returns 5 members.

MAYOR, JOHN EYTON BICKERSTETH (1825–1910), English classical scholar, was born at Baddegama, Ceylon, on Jan. 28, 1825, and educated at Shrewsbury school and St. John's college, Cambridge. He became professor of Latin at Cambridge in 1872. His best-known work is an edition of 13 satires of Juvenal (1853, 3rd ed., 2 vols., 1881). His *Bibliographical Clue to Latin Literature* (1873), and his edition of Cicero's *Second Philippic* are widely used. He also edited Richard of Cirencester's *Speculum historiale de gestis regum Angliae 447–1066* (1863–69); Roger Ascham's *Schoolmaster* (new ed., 1883); the *Latin Heptateuch* (1889); and the *Journal of Philology*. He died at Cambridge on Dec. 1, 1910.

See *Dic. Nat. Biog.* (2nd Suppt.).

MAYOR, in modern times the title of a municipal officer who discharges judicial and administrative functions. The French form of the word is *maire*. In Germany the corresponding title is *bürgermeister*, in Italy *podestà*, in Spain *alcalde* and in Scotland provost. "Mayor" had originally a much wider significance. Among the nations which arose on the ruins of the Roman empire of the West and made use of Latin as their official and legal lan-

guage, *maior* and the Low Latin feminine *maiorissa* were convenient terms to describe important officials of both sexes who had the superintendence of others. So the male officer who governed the king's household would be the *maior domus*. In the households of the Frankish kings of the Merovingian line, the *maior domus*, who was also variously known as the *gubernator*, *rector*, *moderator* or *praefectus palatii*, was so great an officer that he ended by evicting his master. He was the "mayor of the palace" (*q.v.*). Beside the *maior domus* (the major-domo), there were other officers who were *maiores*, the *maior cubiculi*, mayor of the bedchamber, and *maior equorum*, mayor of the horse.

A word which could be applied so easily and in so many circumstances was certain to be widely used, and the post-Augustine, *maiorinus*, "one of the larger kind," was the origin of the mediaeval Spanish *merinus*, who in Castilian is the *merino*, and sometimes the *merino mayor*, or chief merino, a judicial and administrative officer of the king's. The *gregum merinus* was the superintendent of the flocks of the corporation of sheep-owners called the *mesta*, whence the sheep, and then the wool, have come to be known as *merino*—a word identical in origin with the municipal title of mayor.

In England the chief officers of the boroughs down to the 11th century were the reeves, sometimes called port reeves. The mayor appears in the 12th century, at the period when municipal life is developing rapidly (*see* BOROUGH), as the elected head of the town government. He held office alongside of the reeves (or bailiffs or, in London, sheriffs), whose duties were first to the king, as the mayor's chief duty was to the community of the borough. London obtained a mayor in 1191, and nine other boroughs had mayors by the end of John's reign. By the middle of the 13th century the practice was general.

A mayor is now in England and America the official head of a municipal government. In Great Britain the Municipal Corporations Act, 1882, regulates the election of the mayor. He is to be a fit person elected annually on Nov. 9 by the council of the borough from among the aldermen or councillors or persons qualified to be such. His term of office is one year, but he is eligible for re-election. He may appoint a deputy to act during illness or absence, and such deputy must be either an alderman or councillor. A mayor who is absent from the borough for more than two months becomes disqualified and vacates his office. A mayor is *ex officio* during his year of office and the next year a justice of the peace for the borough. He receives such remuneration as the council thinks reasonable. The office of mayor in an English borough does not entail any important administrative duties. It is regarded as an honour conferred for past services.

The mayors of certain cities in the British isles (London, York, Dublin) have acquired by prescription the prefix of "lord." In the case of London it seems to date from 1540. It has also been conferred during the closing years of the 19th century by letters patent on other cities—Birmingham, Liverpool, Manchester, Bristol, Sheffield, Leeds, Cardiff, Bradford, Newcastle-on-Tyne, Belfast, Cork. In 1910 it was granted to Norwich; and in 1928 to Nottingham, Leicester, Stoke-on-Trent and Portsmouth. The title "right honourable" is a distinction conferred only upon the lord mayors of London, York, Belfast, Melbourne, Sydney and Adelaide and upon the lord provosts of Edinburgh and Glasgow.

The English method of selecting a mayor by the council is followed for the corresponding functionaries in France (except Paris), the more important cities of Italy, and in Germany, where, however, the central government must confirm the choice of the council. Direct appointment by the central government exists in Belgium, Holland, Denmark, Norway, Sweden and the smaller towns of Italy and Spain. In France election is for four years, in Holland for six, in Belgium for an indefinite period, and in Germany usually for 12 years, but in some cases for life. In France the *maire*, and his "adjuncts" are elected directly by the municipal council from among their own number.

See also A. Shaw, *Municipal Government in Continental Europe* (1901), J. A. Fairlie, *Municipal Administration* (1901); J. Redlich, *Local Government in England*, trans. and ed. F. W. Hirst (1903); S. and B. Webb, *English Local Government* (1906, etc.); A. L. Lowell, *The Government of England* (1920). (X.; H. CA.)

UNITED STATES

The office of mayor in the United States has passed through an interesting evolution. In Colonial days, the mayor was appointed by the provincial or colonial governor, except in Elizabeth, N.J., and in the close corporations of Annapolis, Norfolk and Philadelphia, where the mayor was selected by the local governing body. The duties and powers of the colonial mayor, fashioned in part after those of the contemporary English mayor, were to preside at meetings of the council, to serve as the ceremonial head of the city, to discharge important local judicial functions and to represent the colony in local affairs.

Popular election of the mayor was introduced as early as 1806 (Nashville), but it was not generally adopted until 20 years later (*e.g.*, Boston, St. Louis, 1822; Detroit, 1824; Philadelphia, 1826; Baltimore, 1833; New York, Pittsburgh, 1834; Buffalo, Rochester, Brooklyn, 1840; Milwaukee, 1846; San Francisco, 1850). By the middle of the century practically every mayor was elected. Except in Boston (Josiah Quincy, mayor, six terms, 1823–29), and in a few other cities, the change to an elected mayor resulted in no immediate increase in the influence of the office. Within the next generation, however, due to the increasing complexity of city administration, the corruption and incompetence of councils, the vantage point of publicity and leadership accorded an elected mayor in a complex Government, and, finally the application in city organization of the principle of the separation of powers, which had been for 60 years a fetish in American national and State Government, there was brought about a gradual increase in the powers of the mayor at the expense of the council.

The mayor gradually became the centre of the administrative power of the city; this came about through the power to appoint council committees, to appoint and remove administrative officials and to investigate city departments. Though the mayor was frequently deprived of his seat in the council, as his new isolation developed, his influence in legislation was augmented through the veto power (first granted in New York, 1830), through the power to recommend legislation and through his strategic advantage in marshalling public opinion behind his programme.

By 1900 the mayor had thus become the dominating influence and centre of authority in American city government. The widespread introduction of executive budget systems in the cities (1907–15) and the spread of municipal home rule, have served still further to augment the powers of the mayor.

The Constitution of the Mayoralty at the present time may be summarized as follows, though the legal provisions and practices in the United States vary from State to State and from city to city within the same State. The mayor is the chief executive officer of the city, except in the commission and council-manager forms of government. He generally appoints the heads of the administrative departments, including such services as police, public works, health, poor relief and fire protection.

In legislative matters, though generally not a member of the council, the mayor tends to dominate the situation through his power to recommend legislation, his limited veto, his special prerogatives in fiscal legislation and his general prestige. The mayor as a chief executive is always popularly elected. He must be a local resident and elector, though in a few cases a higher age limit is set than for voters (*e.g.*, Philadelphia, Baltimore, Charleston, Montana, etc.), and in some jurisdictions the payment of taxes is a prerequisite (*e.g.*, Baltimore, Seattle, etc.). The position is universally open to women. Elections are usually held in November with other local, State and national elections, though there has been a tendency in recent years to bring about a segregation of elections.

The term of office is now generally two or four years, the longer term being almost universal in the largest cities. The mayor is subject to removal in all jurisdictions, generally by court action, though in some cases by the recall (*e.g.*, Los Angeles, San Francisco, Seattle, Boston, etc.), or by the State governor (New York and Ohio). Removals are, however, extremely rare and except where the recall is used, are known only for gross misfeasance. The mayor, except in the smallest cities, is generally a salaried official; compensation thus ranges to $25,000 a year in

New York. Re-election of the mayor is common except in a few cities where successive terms are prohibited. Because of his position and powers, the mayor is the official spokesman and ceremonial head of the city and during his term of office, at least, holds a unique position in the community.

There are in the United States some 2,000 cities. In about 1,450 of these cities the chief executive officer is the mayor. In some 350 cities which are governed and administered by a small elected commission, and in 300 cities governed by a small elected commission and administered through a city manager appointed by the commission, though the office of mayor generally exists, the duties are restricted to serving as the presiding officer of the council and acting as ceremonial head of the municipality.

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MAYOR OF THE PALACE. The office of mayor of the palace was an institution peculiar to the Franks of the Merovingian period. A landowner who did not manage his own estate placed it in the hands of a steward (*maior*), who superintended the working of the estate and collected its revenues. If he had several estates, he appointed a chief steward, who managed the whole of the estates and was called the *maior domus*. Each great personage had a *maior domus;* and since the royal house was called the palace, this officer took the name of "mayor of the palace." The mayor of the palace, however, did not remain restricted to domestic functions; he had the discipline of the palace and tried persons who resided there. Soon his functions expanded. If the king were a minor, the mayor of the palace supervised his education in the capacity of guardian (*nutricius*), and often also occupied himself with affairs of State. When the king came of age, the mayor exerted himself to keep this power, and succeeded. In the 7th century he became the head of the administration and a veritable prime minister. He took part in the nomination of the counts and dukes; in the king's absence he presided over the royal tribunal; and he often commanded the armies. When the custom of commendation developed, the king charged the mayor of the palace to protect those who had commended themselves to him and to intervene at law on their behalf. The mayor of the palace thus found himself at the head of the *commendati,* just as he was at the head of the functionaries.

The succession of the early mayors of the palace is obscure. When the office increased in importance the mayors of the palace did not, as has been thought, pursue an identical policy. Some—for instance, Otto, the mayor of the palace of Austrasia towards 640—were devoted to the Crown. On the other hand, mayors like Flaochat (in Burgundy) and Erkinoald (in Neustria) stirred up the great nobles against the king. Others again, sought to exercise the power in their own name both against the king and against the great nobles—such as Ebroïn (in Neustria), and later, the Carolingians Pippin II., Charles Martel and Pippin III., who, after making use of the great nobles, kept the authority for themselves. In 751 Pippin III., fortified by his consultation with Pope Zacharias, could quite naturally exchange the title of mayor for that of king; and when he became king, he suppressed the title of mayor of the palace. It must be observed that from 639 there were generally separate mayors of Neustria, Austrasia and Burgundy, even when Austrasia and Burgundy formed a single kingdom; the mayor was a sign of the independence of the region. Each mayor, however, sought to supplant the others; the Pippins and Charles Martel succeeded, and their victory was at the same time the victory of Austrasia over Neustria and Burgundy.

See G. H. Pertz, *Geschichte der merowingischen Hausmeier* (Hanover, 1819); H. Bonnell, *De dignitate majoris domus* (Berlin, 1858); E. Hermann, *Das Hausmeieramt, ein echt germanisches Amt,* vol. ix. of *Untersuchungen zur deutschen Staats- und Rechtsgeschichte,* ed. by O. Gierke (Breslau, 1878, *seq.*); G. Waitz, *Deutsche Verfassungsgeschichte,* 3rd ed., revised by K. Zeumer; and Fustel de Coulanges, *Histoire des institutions politiques de l'ancienne France: La monarchie franque* (1888). (C. PF.)

MAYOTTE, one of the Comoro islands, in the Mozambique channel between Madagascar and the African mainland. It has belonged to France since 1843. (*See* COMORO ISLANDS.) The fertile lands grow the vanilla. Dzaoudzi is the chief centre of the archipelago.

MAYOW, JOHN (1643–1679), English chemist and physiologist (F.R.S., 1668), was born in London in May 1643. In 1658 he went up to Wadham college, Oxford, of which he became a scholar a year later, and in 1660 he was elected to a fellowship at All Souls. He graduated in law (bachelor, 1665, doctor, 1670), but made medicine his profession. He died in London in September 1679. He published at Oxford in 1668 two tracts, on respiration and rickets, and in 1674 these were reprinted, the former in an enlarged and corrected form, with three others, "De sal-nitro et spiritu nitro-aereo," "De respiratione foetus in utero et ovo," and "De motu musculari et spiritibus animalibus" as *Tractatus quinque medico-physici.* The contents of this work, which was translated into Dutch, German and French, show him to have been an investigator much in advance of his time.

Mayow, who gives a remarkably correct anatomical description of the mechanism of respiration, preceded Priestley and Lavoisier by a century in recognizing the existence of oxygen, under the guise of his *spiritus nitro-aereus,* as a separate entity distinct from the general mass of the air; he perceived the part it plays in combustion and in increasing the weight of the calces of metals as compared with metals themselves.

MAYSVILLE, a city of Kentucky, U.S.A., the county seat of Mason county; on the Ohio river at the mouth of Limestone creek, 60 m. S.E. of Cincinnati. It is on Federal highway 68, and is served by the Chesapeake and Ohio and the Louisville and Nashville railways and river steamers. Pop. (1920) 6,107; 6,557 in 1930. It has various manufacturing industries, and is an important shipping point for tobacco, live stock and wheat. Formerly it was one of the principal hemp markets of the country. The site was an early landing point for pioneers coming into Kentucky, and in 1784 a blockhouse and a double log cabin were erected. In 1787 John May (killed by the Indians in 1790) and Simon Kenton laid out the town and it was incorporated. It was chartered as a city in 1833 and became the county seat in 1848. The turnpike from Maysville to Lexington, completed in 1835, was the first of a system of roads built with State aid.

MAYWOOD, a village of Cook county, Illinois, U.S.A., on the Desplaines river, 12 m. W. of the Chicago "loop." It is served by the Chicago and North Western, the Chicago Great Western, the Chicago, Aurora and Elgin and the Indiana Harbor Belt railways, and trolley lines connecting with the Chicago system. Pop. 12,072 in 1920 (21% foreign-born white); and 25,829 in 1930 (Federal census). It is primarily a residential suburb, but there are wholesale rose gardens and various manufacturing industries, including a tin-can plant which normally employs 1,000 workers, and factories making ginger ale, marshmallows, branding irons and locomotive packings. The village was founded in 1869 by Col. William Nichols and two friends (all from Vermont), who purchased 600 ac. and were incorporated as a real estate company to develop the tract. There was a wood skirting the site on the east, and Col. Nichols had a daughter, May; hence the name. The first factory (now the can factory) was built by the company to provide employment in the hard times following the panic of 1873. Incorporation as a village was completed in 1881.

MAZAGAN (*El Jadīda*), a port on the Atlantic coast of Morocco, in 33° 16′ N. 8° 26′ W., at the bottom of a bay rocky at the extremities, sandy in the centre, a little way to the south of the mouth of the Oum-er-Rbīa. The walls, the gates surmounted by the escutcheons of the kings of Portugal, the old strong castle, all recall the Portuguese origin of Mazagan. The most remarkable building is the magnificent *salle-d'armes,* which served as a storehouse after the completion of the ramparts (1541). The new town stretches to the north and to the south of the old town. The port is constituted of an outer dock of 7 hectares, protected by two jetties, into which open the old wet-dock and a shelter for small boats. The trade amounts to 166 million francs, of which 51 millions represent imports and 115 millions exports. The share of France is 59 millions, that of Great Britain 25 millions. The exports are mainly the agricultural

products of the rich region of Doukkala, notably eggs; the imports, cotton goods destined for Marrakesh The pop. (1931) is 20,834, of whom 15,411 are Muslim, 3,288 Jews, and 2 135 Europeans. Mazagan is the chief town of the *controle civil* of Doukkala.

Mazagan, founded by the Portuguese in 1502, was the centre of their settlement in Morocco and the last place which they kept there; they evacuated it in 1769 The growth of the town dates from the French protectorate (1912).

See J. Goulven, *La place de Mazagan sous la domination portugaise* (1917), and *British Consular Reports*.

MAZAMET, an industrial town of south-western France in the department of Tarn, 41 m S S E of Albi by rail. Pop. (1931) 11 550. Mazamet is situated on the northern slope of the Montagnes Noires and on the Arnette, a small sub-tributary of the Agout. Its industries are wool-spinning and the manufacture of "swan-skins," flannels and hosiery, and there are important tanneries and leather-dressing, glove and dye works. Wool and raw hides are imported from abroad.

MAZANDERAN, a province of Persia, lying between the Caspian Sea and the Elburz range and bounded E. by the province of Astarabad and W. by Gilan; about 200 m. long by 60 m. Mazanderan, like Gilan, comprises two distinct natural regions, presenting the sharpest contrasts. The northern portion consists of swampy lowlands, varying in breadth from 10 to 30 m. partly under impenetrable jungle and partly under crops. This belt is fringed northward by the Caspian, here almost destitute of good natural harbours, and rises somewhat abruptly inland to the second belt comprising the northern slopes and spurs of the Elburz which are almost everywhere covered with dense forest. The lowlands, rising but a few feet above the sea, and subject to frequent floodings, are malarious while the highlands, culminating in Mt Demavend (18,600 ft) enjoy a tolerably healthy climate; but the climate is capricious. Snow falls in the highlands, where for weeks it completely blocks the tracks across the Elburz. The rivers of Mazanderan are comparatively short and little more than mountain torrents. The chief is the Harhaz rising in the neighbourhood of Demavend; all are well stocked with trout, salmon, perch, carp and sturgeon.

Production.—The chief natural products of the lowlands are rice, cotton of good quality, sugar-cane, silk and citrus fruits. Hazar Jarib grows wheat and barley; while the hill district of Firuzkuh has extensive summer pastures. The main forests—of oak, ash, box, walnut, etc., are in the *miyanabad*, or middle hills. Wild boars are numerous. The domestic animals are small, including the black humped cattle, sheep and goats. Mazanderan is rich in minerals and in the Nur district iron in exploitable quantities is found in proximity to coal.

Population.—Mazanderan is divided into the ten districts of Ashraf, Hazar Jarib, Sari, Savad Kuh, Aliabad, Firuzkuh, Meshed-i-Sar, Barfurush, Bandipe, Amol and Larijan, and Nur. The coastal plains are probably the most thickly-peopled tracts in Persia, especially the delta areas at the mouths of the rivers where water can be utilized for rice cultivation. The two races chiefly represented are the Mazanderani and Gilaki. The capital is Barfurush (*q.v.*). For short periods this town has been the administrative headquarters, but usually the Governor of Mazanderan resides at Sari. The export trade is chiefly with the port of Baku and carried on almost exclusively from Meshed-i-Sar at the mouth of the Babil river, navigable for small craft up to Barfarush, 15 m. inland. The tonnage of trade in 1925–26 was 19,000 tons. Great quantities of rice are sent into the interior of Persia, principally to Tehran and Kazvin. The imports in order of value were sugar, flour, tea and metals and minerals. A salient feature of the Caspian provinces is their isolation from the rest of Persia by the formidable barrier of Elburz. The road from Tehran to Demavend, constructed in 1919 by the Persian postal administration, is passable for all classes of motors at most seasons.

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MAZARIN, JULES (1602–1661), French cardinal and statesman, elder son of a Sicilian, Pietro Mazarini, the intendant of the household of Philip Colonna, and of his wife Ortensia Buffalini, a connection of the Colonnas, was born at Piscina in the Abruzzi on July 14, 1602. He was educated by the Jesuits at Rome till his seventeenth year, when he accompanied Jerome Colonna as chamberlain to the university of Alcala in Spain. On his return to Rome, about 1622, he took his degree as Doctor *utriusque juris*, and then became captain of infantry in the regiment of Colonna, which took part in the war in the Valtelline Pope Urban VIII. entrusted him, in 1629, with the difficult task of putting an end to the war of the Mantuan succession. He was presented to two canonries in the churches of St. John Lateran and Sta. Maria Maggiore, although he had only taken the minor orders, and had never been consecrated priest; he negotiated the treaty of Turin between France and Savoy in 1632, became vice-legate at Avignon in 1634, and nuncio at the court of France from 1634 to 1636. Seeing that he had no chance of becoming a cardinal except by the aid of some great power, he accepted Richelieu's offer of entering the service of the king of France, and in 1639 became a naturalized Frenchman.

In 1640 Richelieu sent him to Savoy, where the regency of Christine, the duchess of Savoy, and sister of Louis XIII., was disputed by her brothers-in-law, the princes Maurice and Thomas of Savoy, and he succeeded not only in establishing Christine but in winning over the princes to France. He was rewarded by promotion to the rank of cardinal on the presentation of the king of France in Dec. 1641. On Dec. 4, 1642, Richelieu died, and was succeeded as minister by Mazarin. The new minister ingratiated himself with the queen, who would be regent after the king's death. Louis XIII. died on May 14, 1643, and Mazarin retained office. His skilful policy was shown in every arena on which the great Thirty Years' War was being fought out. Mazarin had inherited the policy of France during the Thirty Years' War from Richelieu. He had inherited his desire for the humiliation of the house of Austria in both its branches, his desire to push the French frontier to the Rhine and maintain a counterpoise of German states against Austria, his alliances with the Netherlands and with Sweden, and his four theatres of war—on the Rhine, in Flanders, in Italy and in Catalonia.

During the last five years of the great war it was Mazarin alone who directed the French diplomacy of the period. He made the peace of Brömsebro between the Danes and the Swedes, and turned the latter once again against the empire; he sent Lionne to make the peace of Castro, and combine the princes of North Italy against the Spaniards, and he made the peace of Ulm between France and Bavaria, thus detaching the emperor's best ally. He made one fatal mistake—he dreamt of the French frontier being the Rhine and the Scheldt, and that a Spanish princess might bring the Spanish Netherlands as dowry to Louis XIV. This roused the jealousy of the United Provinces, and they made a separate peace with Spain in January 1648; but Turenne's victory at Zusmarshausen, and Condé's at Lens led to the peace of Westphalia (1648).

At home Mazarin's policy lacked the strength of Richelieu's. The Frondes were largely due to his own fault. The arrest of Broussel threw the people on the side of the parlement. His avarice and unscrupulous plundering of the revenues of the realm, the enormous fortune which he thus amassed, his supple ways, his nepotism, and the general lack of public interest in the great foreign policy of Richelieu, made Mazarin the especial object of hatred both by bourgeois and nobles. He had tried consistently to play off the king's brother Gaston of Orleans against Condé, and their respective followers against each other, and had also, as his *carnets* prove, jealously kept any courtier from getting into

the good graces of the queen-regent except by his means, so that it was not unnatural that the nobility should hate him, while the queen found herself surrounded by his creatures alone. Events followed each other quickly; the day of the barricades was followed by the peace of Ruel, the peace of Ruel by the arrest of the princes, by the battle of Rethel, and Mazarin's exile to Brühl before the union of the two Frondes.

In exile at Brühl Mazarin saw the mistake he had made in isolating himself and the queen, and that his policy of balancing every party in the state against each other had made every party distrust him. So by his counsel the queen, while nominally in league with De Retz and the parliamentary Fronde, laboured to form a purely royal party, wearied by civil dissensions, who should act for her and her son's interest alone, under the leadership of Mathieu Molé, the famous premier president of the parlement of Paris. The new party grew in strength, and in January 1652, after exactly a year's absence, Mazarin returned to the court. In order to promote a reconciliation with the parlement of Paris Mazarin had again retired from court, this time to Sedan, in August 1652, but he returned finally in February 1653. He had retrieved his position by founding that great royal party which steadily grew until Louis XIV. could fairly have said "L'État, c'est moi." As the war had progressed, Mazarin had steadily followed Richelieu's policy of weakening the nobles on their country estates. Whenever he had an opportunity he destroyed a feudal castle, and by destroying the towers which commanded nearly every town in France, he freed such towns as Bourges, for instance, from their long practical subjection to the neighbouring great lord.

The Fronde over, Mazarin had to build up afresh the power of France at home and abroad. Beyond destroying the brick-and-mortar remains of feudalism, he did nothing for the people. But abroad his policy was everywhere successful, and opened the way for the policy of Louis XIV. By means of an alliance with Cromwell, he recovered the north-western cities of France, though at the price of yielding Dunkirk to the Protector. On the Baltic, France guaranteed the Treaty of Oliva between her old allies Sweden, Poland and Brandenburg, which preserved her influence in that quarter. In Germany he, through Hugues de Lionne, formed the league of the Rhine, by which the states along the Rhine bound themselves under the headship of France to be on their guard against the house of Austria. By the Treaty of the Pyrénées Spain recovered Franche Comté, but ceded to France Roussillon, and much of French Flanders; and what was of greater ultimate importance to Europe, Louis XIV. was to marry a Spanish princess. He died at Vincennes on March 9, 1661, leaving a fortune estimated at from 18 to 40 million livres behind him, and his nieces married into the greatest families of France and Italy.

Mazarin was not a Frenchman, but a citizen of the world, and always paid most attention to foreign affairs; in his letters all that could teach a diplomatist is to be found, broad general views of policy, minute details carefully elaborated, keen insight into men's characters, cunning directions when to dissimulate or when to be frank. Italian though he was by birth, education and nature, France owed him a great debt for his skilful management during the early years of Louis XIV., and the king owed him yet more, for he had not only transmitted to him a nation at peace, but had educated for him his great servants Le Tellier, Lionne and Colbert. Literary men owed him also much; not only did he throw his famous library open to them, but he pensioned all their leaders, including Descartes, Vincent Voiture (1598–1648), Jean Louis Guez de Balzac (1597–1654) and Pierre Corneille.

(H. M. St.; X.)

Bibliography.—*See* P. A. Chéruel, *Histoire de France pendant la minorité de Louis XIV.*, 4 vols. (1879–1880), which covers from 1643–1651, and its sequel *Histoire de France sous le ministère de Cardinal Mazarin*, 2 vols. (1881–82), which is the first account of the period written by one able to sift the statements of De Retz and the memoir writers, and rest upon such documents as Mazarin's letters and *carnets*. Mazarin's *Lettres* appeared in the *Collection des documents inédits*, 9 vols. For his early life to Cousin's *Jeunesse de Mazarin* (1865), and for the careers of his nieces to Renée's *Les Nièces de Mazarin* (1856). For the Mazarinades or squibs written against him in Paris during the Fronde, *see* C. Moreau's *Bibliographie des mazarinades* (1850), containing an account of 4,082 Mazarinades. *See* also A. Hassall, *Mazarin* (1903); Roca, *De Richelieu à Mazarin* (1908); C. Federn, *Mazarin* (Munich, 1922).

MAZAR-I-SHARIF, a town of Afghanistan, the capital of the province of Afghan Turkestan. Owing to the importance of the military cantonment of Takhtapul, and its religious sanctity, it has long ago supplanted the more ancient capital of Balkh. It is situated in a malarious, almost desert plain, 9 m. E. of Balkh, and 30 m. S. of the Pata Kesar ferry on the Oxus river. In this neighbourhood is concentrated most of the Afghan army north of the Hindu Kush mountains, the fortified cantonment of Dehdadi having been completed by Sirdar Ghulam Ali Khan and incorporated with Mazar. Mazar-i-Sharif also contains a celebrated mosque, from which the town takes its name. Built by Sultan Ali Mirza about A.D. 1420, it is held in great veneration by all Mussulmans, and especially by Shiites, because it is supposed to be the tomb of Ali, the son-in-law of Mohammed

MAZARRÓN, a town of eastern Spain, in the province of Murcia, 19 m. W. of Cartagena. Pop. (1930), 14,120. There are soap and flour mills and metallurgic factories in the town, and iron, copper and lead mines in the neighbouring Sierra de Almenara. A railway 5 m. long unites Mazarrón to its port on the Mediterranean, which has important leadworks.

MAZATLÁN, a city and port of the State of Sinaloa, Mexico, reached by the Southern Pacific of Mexico railway. Pop. (1926) 28,000. The harbour is spacious and is provided with a sea wall at Olas Altas, but the entrance is obstructed by a bar. The city is built on a small peninsula. Its public buildings include a fine town-hall, chamber of commerce, a custom-house and two hospitals, besides which there is a nautical school and a meteorological station, one of the first established in Mexico. A Government wireless telegraph service is maintained between Mazatlán and La Paz, Lower California. Among the manufactories are saw-mills, foundries, cotton factories and ropeworks; the exports are chiefly hides, ixtle, dried and salted fish, gold, silver and copper (bars and ores), fruit, tortoise-shell and gums and resins.

MAZE: *see* Labyrinth.

MAZEPA-KOLEDINSKY, IVAN STEPANOVICH (1644?–1709), hetman of the Cossacks, belonging to a noble Orthodox family, was born possibly at Mazeptsina, either in 1629 or 1644, the latter being the more probable date. He was educated at the court of the Polish king, John Casimir, and completed his studies abroad. An intrigue with a Polish married lady forced him to fly into the Ukraine. There is a trustworthy tradition that the infuriated husband tied the naked youth to the back of a wild horse and sent him forth into the steppe. He was rescued and cared for by the Dnieperian Cossacks, and speedily became one of their ablest leaders. In 1687, during a visit to Moscow, he won the favour of the then all-powerful Vasily Golitsuin, from whom he virtually purchased the hetmanship of the Cossacks (July 25). He took a very active part in the Azov campaigns of Peter the Great and won the entire confidence of the young tsar by his zeal and energy. He was also very serviceable to Peter at the beginning of the Great Northern War, especially in 1705 and 1706, when he took part in the Volhynian campaign and helped to construct the fortress of Pechersk. The power and influence of Mazepa were fully recognized by Peter the Great. No other Cossack hetman had ever been treated with such deference at Moscow. He ranked with the highest dignitaries in the state; he sat at the tsar's own table.

Mazepa had no temptations to be anything but loyal, and loyal he would doubtless have remained had not Charles XII. crossed the Russian frontier. Then it was that Mazepa, who had had doubts of the issue of the struggle all along, made up his mind that Charles, not Peter, was going to win. But he proceeded cautiously. Indeed, he would have preferred to remain neutral, but he was not strong enough to stand alone. The crisis came when Peter ordered him to co-operate actively with the Russian forces in the Ukraine. At this very time he was in communication with Charles's first minister, Count Piper, and had agreed to harbour the Swedes in the Ukraine and close it against

the Russians (Oct. 1708). The last doubt disappeared when Menshikov was sent to supervise Mazepa. At the approach of his rival the old hetman hastened to the Swedish outposts at Horki, in Severia. Mazepa's treason took Peter completely by surprise. He instantly commanded Menshikov to get a new hetman elected and raze Baturin, Mazepa's chief stronghold in the Ukraine, to the ground. The metropolitan of Kiev solemnly excommunicated Mazepa from the high altar, and his effigy was publicly burnt by the common hangman.

Henceforth Mazepa, perforce, attached himself to Charles. What part he took at the battle of Poltava is not quite clear. After the catastrophe he accompanied Charles to Turkey with some 1,500 horsemen (the miserable remnant of his 80,000 warriors). The sultan refused to surrender him to the tsar, though Peter offered 300,000 ducats for his head. He died at Bender on Aug. 22, 1709.

See N. I. Kostomarov, *Mazepa and the Mazepanites* (Russ.) (St. Petersburg, 1885); R. Nisbet Bain, *The First Romanovs* (London, 1905); S. M. Solovev, *History of Russia* (Russ.), vol. xv. (St. Petersburg, 1895).

MAZLUM PASHA, AHMED (d. 1928), Egyptian statesman, entered the Egyptian cabinet in 1893, and was minister of finance from 1895 to 1908. He had thus a very long official experience when the constitutional changes inaugurated by Lord Kitchener in 1911–14 were effected. Mazlum Pasha was the first president of the Legislative Assembly established in 1913, and he held office until 1923. After an interval, during which he was minister of *wafks* (pious foundations) under Zaghlul Pasha, in 1924 he resumed the presidency of the Assembly for a few months. Mazlum Pasha's family was partly Turkish in origin, and he remained a typical Turkish gentleman. He died on May 8, 1928.

MAZURKA, a lively dance, originating in Poland, somewhat resembling the polka. It is danced in couples, the music being in $\frac{3}{8}$ or $\frac{3}{4}$ time.

MAZZARA DEL VALLO, a town of Sicily, province of Trapani, on the south-west coast of the island, 32 m. by rail S. of Trapani. Pop. (1931), 24,245. It has a cathedral (1093) rebuilt in the 17th century, and a castle (1073). Mazzara was in origin a colony of Selinus: it was destroyed in 409, but was a Carthaginian fortress in the First Punic War and a station on the Roman coast road.

MAZZINI, GIUSEPPE (1805–1872), Italian patriot, was born on June 22, 1805, at Genoa. During infancy and childhood his health was extremely delicate; but he soon began to devour books of all kinds and to show other signs of great intellectual precocity. He became a student at the University of Genoa at an unusually early age, and decided to graduate in law (1826). His exceptional abilities, together with his remarkable generosity, kindness and loftiness of character, endeared him to his fellow students.

The natural bent of his genius was towards literature, and he wrote a considerable number of essays and reviews, some of which have been wholly or partially reproduced in the critical and literary volumes of his *Life and Writings*. But he held the idea that Italians, and he himself in particular, "*could* and therefore *ought* to struggle for liberty of country." Therefore, he at once put aside his literary ambitions, and devoted himself to politics. His articles accordingly became more and more suggestive of advanced liberalism in politics. Having joined the Carbonari, shortly after the French revolution of 1830, he was betrayed and imprisoned in the fortress of Savona for about six months; a conviction having been found impracticable through deficiency of evidence, he was released, but forced to go into exile. He withdrew accordingly into France, living chiefly in Marseilles.

While in his lonely cell at Savona, he had finally become aware of the great mission or "apostolate" (as he himself called it) of his life; and soon after his release his prison meditations took shape in the programme of the organization which was destined soon to become so famous throughout Europe, that of *La Giovine Italia,* or Young Italy. Its aims were the liberation of Italy both from foreign and domestic tyranny, and its unification under a republican form of government; the means to be used were education, and, where advisable, revolt by guerrilla bands. In April 1831 Charles Albert, "the ex-Carbonaro conspirator of 1821," succeeded Charles Felix on the Sardinian throne, and towards the close of that year Mazzini wrote the new king a letter, published at Marseilles, urging him to take the lead in the impending struggle for Italian independence. Representations were consequently made by the Sardinian to the French government, which issued an order for Mazzini's withdrawal from Marseilles (Aug. 14, 1832); he ultimately found it necessary to retire into Switzerland.

In 1833 he was concerned in an abortive revolutionary movement which took place in the Sardinian army; several executions took place, and he himself was laid under sentence of death. Before the close of the same year a similar movement in Genoa had been planned, but failed through the youth and inexperience of the leaders. At Geneva, also in 1833, Mazzini set on foot *L'Europe Centrale,* a journal of which one of the main objects was the emancipation of Savoy. The frontier was actually crossed on Feb. 1, 1834, but the attack ignominiously broke down without a shot having been fired.

In April 1834 the "Young Europe" association "of men believing in a future of liberty, equality and fraternity for all mankind," was formed also under the influence of Mazzini; it was followed soon afterwards by a "Young Switzerland" society. Mazzini was permitted to remain at Grenchen in Solothurn for a while, but the Swiss diet exiled him at the end of 1836. In Jan. 1837 he arrived in London, where for many months he had to carry on a hard fight with poverty. As he gained command of the English language, he began to earn a livelihood by writing review articles, some of which have since been reprinted, and are of a high order of literary merit. In 1839 he entered into relations with the revolutionary committees sitting in Malta and Paris, and in 1840 he originated a working men's association, and the weekly journal entitled *Apostolato Popolare,* in which the admirable popular treatise "On the Duties of Man" was begun.

The most memorable episode in his life during the same period was perhaps that which arose out of the conduct of Sir James Graham, the home secretary, in systematically, for some months, opening Mazzini's letters as they passed through the British post office, and communicating their contents to the Neapolitan government—a proceeding which was believed at the time to have led to the arrest and execution of the brothers Bandiera, Austrian subjects, who had been planning an expedition against Naples, although the publication of Sir James Graham's life seems to exonerate him from the charge. In this connection Thomas Carlyle wrote to *The Times:* "I have had the honour to know Mr. Mazzini for a series of years, and, whatever I may think of his practical insight and skill in worldly affairs, I can with great freedom testify that he, if I have ever seen one such, is a man of genius and virtue, one of those rare men, numerable unfortunately but as units in this world, who are worthy to be called martyr souls; who in silence, piously in their daily life, practise what is meant by that."

Towards the end of 1847 Mazzini published a letter addressed to the new pope, Piux IX., indicating the nature of the religious and national mission which the Liberals expected him to undertake. The leaders of the revolutionary outbreaks in Milan and Messina in the beginning of 1848 had long been in secret correspondence with Mazzini; and their action, along with the revolution in Paris, brought him early in the same year to Italy, where he took a great and active interest in the events which dragged Charles Albert into a war with Austria; he actually for a short time bore arms under Garibaldi immediately before the reoccupation of Milan. In the beginning of the following year he was nominated a member of the short-lived provisional government of Tuscany formed after the flight of the grand-duke, and almost simultaneously, when Rome had, in consequence of the withdrawal of Pius IX., been proclaimed a republic, he was declared a member of the constituent assembly there. A month afterwards, the battle of Novara having again decided against Charles Albert in the brief struggle with Austria, into which he had once more been drawn, Mazzini was appointed a member of the Roman triumvirate, with supreme executive power (March 23, 1849). Rome was now invested by the French, and that Mazzini suc-

ceeded, however, for so long a time, and in circumstances so adverse, in maintaining a high degree of order within the turbulent city is a fact that speaks for itself. The surrender of the city on June 30 was followed by Mazzini's not too precipitate flight by way of Marseilles into Switzerland, whence he once more found his way to London. He had a firm belief in the value of revolutionary attempts, however hopeless they might seem; he had a hand in the abortive rising at Mantua in 1852; and again a considerable share in the ill-planned insurrection at Milan on Feb. 6, 1853, the failure of which greatly weakened his influence.

The year 1857 found him yet once more in Italy, where, for complicity in émeutes which took place at Genoa, Leghorn and Naples, he was again laid under sentence of death. Undiscouraged in the pursuit of the one great aim of his life, he returned to London, where he edited his new journal *Pensiero ed Azione*, in which the constant burden of his message to the overcautious, practical politicians of Italy was: "I am but a voice crying *Action;* but the state of Italy cries for it also. So do the best men and people of her cities. Do you wish to destroy my influence? *Act.*" The same tone was at a somewhat later date assumed in the letter he wrote to Victor Emmanuel, urging him to put himself at the head of the movement for Italian unity, and promising republican support. As regards the events of 1859–60, however, it may be questioned whether, through his characteristic inability to distinguish between the ideally perfect and the practically possible, he did not actually hinder more than he helped the course of events by which the realization of so much of the great dream of his life was at last brought about. After the irresistible pressure of the popular movement had led to the establishment not of an Italian republic but of an Italian kingdom, Mazzini could honestly enough write, "I too have striven to realize unity under a monarchical flag," but candour compelled him to add, "The Italian people are led astray by a delusion; . . . but monarchy will never number me amongst its servants or followers."

In 1865, as protest against the uncancelled sentence of death under which he lay, Mazzini was elected by Messina to the Italian parliament, but, feeling unable to take the oath of allegiance to the monarchy, he never took his seat. In the following year, when a general amnesty was granted after the cession of Venice to Italy, the sentence of death was at last removed. In May 1869 he was again expelled from Switzerland at the instance of the Italian government for having conspired with Garibaldi; after a few months spent in England he set out (1870) for Sicily, but was promptly arrested at sea and carried to Gaeta, where he was imprisoned for two months. The occasion of the birth of a prince was seized for restoring him to liberty. In the last years of his life he attempted to organize the working classes of Italy on a democratic semi-mystical basis, and he entered into relations with the leading internationalists such as Marx and Bakunin. But he could not work with them and soon lost all touch with working-class circles and was deeply disappointed at the growing influence of the Socialists. He died at Pisa on March 10, 1872. The Italian parliament, by a unanimous vote, expressed the national sorrow with which the tidings of his death had been received. A public funeral took place at Pisa on March 14, and the remains were afterwards conveyed to Genoa.

Bibliography.—The published writings of Mazzini, mostly occasional, are very voluminous. An edition was begun by himself and continued by A. Saffi, *Scritti editi e inediti di Giuseppe Mazzini,* (1861–91); many of the most important are found in the partially autobiographical *Life and Writings of Joseph Mazzini* (1864–70) and the two most systematic—*Thoughts upon Democracy in Europe,* a remarkable series of criticisms on Benthamism, St. Simonianism, Fourierism, and other economic and socialistic schools of the day, and the treatise *On the Duties of Man,* an admirable primer of ethics, dedicated to the Italian working class—will be found in *Joseph Mazzini: a Memoir,* by Mrs. E. A. Venturi (1875). Of the 40,000 letters of Mazzini only a small part have been published. In 1887 two hundred unpublished letters were printed at Turin (*Duecento lettere inedite di Giuseppe Mazzini*); in 1895 the *Lettres intimes* were published in Paris, and in 1905 Francesco Rosso published *Lettere inedite di Giuseppe Mazzini* (Turin, 1905). A popular edition of Mazzini's writings has been undertaken by order of the Italian government.

For Mazzini's biography *see* Jessie White Mario, *Della vita di Giuseppe Mazzini* (Milan, 1886), a useful if somewhat too enthusiastic work; Bolton King, *Mazzini* (1903); A. Luzio's *Giuseppe Mazzini* (Milan, 1905) contains a great deal of valuable information, bibliographical and other, and Dora Melegari in *La giovine Italia e Giuseppe Mazzini* (Milan, 1906) publishes the correspondence between Mazzini and Luigi A. Melegari during the early days of "Young Italy." Nello Rosselli, *Mazzini e Bakounini* (Turin, 1927) is important for the last phase of his life. For the literary side of Mazzini's life *see* Peretti, *Gli scritti letterarii di Giuseppe Mazzini* (Turin, 1904).

(J. S. B., L. V.)

MAZZONI, GIACOMO (1548–1598), Italian philosopher, was born at Cesena and died at Ferrara. He occupied chairs in the universities of Pisa and Rome, was one of the founders of the Della Crusca Academy, and had the distinction, it is said, of thrice vanquishing the Admirable Crichton in dialectic. He published in 1597 *In universam Platonis et Aristotelis philosophiam praecludia.* He also wrote *De triplici hominum vita,* wherein he outlined a theory of the infinite perfection and development of nature, and two works in defence of Dante: *Discorso composto in difesa della comedia di Dante* (1572), and *Della difesa della comedia di Dante* (1587, reprinted 1688) He was an authority on ancient languages and philology, and gave a great impetus to the scientific study of the Italian language.

MAZZONI, GUIDO (1859–), Italian poet, was born at Florence, and educated at Pisa and Bologna. He became professor of Italian at Padua, 1887, and at Florence, 1894. He was influenced by Carducci. His chief volumes of verse are *Versi* (1880), *Nuove poesie* (1886), *Poesie* (1891), *Voci della vita* (1893).

Mc, M‘, are alphabetized as Mac in this work.

MEAD, LARKIN GOLDSMITH (1835–1910), American sculptor, was born at Chesterfield, N.H., on Jan. 3, 1835. He was a pupil (1853–55) of Henry Kirke Brown. During the early part of the Civil War he was at the front for six months as an artist for *Harper's Weekly*; and in 1862–65 he was in Italy, part of the time attached to the United States consulate at Venice, while William D. Howells, his brother-in-law, was consul. He returned to America in 1865, but subsequently went back to live at Florence. His first important work was a statue of Ethan Allen, now at the State House, Montpelier, Vermont. His principal works are: the monument to President Lincoln, Springfield, Ill.; "Ethan Allen" (1876), National Hall of Statuary, Capitol, Washington; an heroic marble statue, "The Father of Waters," New Orleans; and "Triumph of Ceres," made for the Columbian Exposition, Chicago. He died at Florence on Oct. 15, 1910.

MEAD, RICHARD (1673–1754), English physician, 11th child of Matthew Mead (1630–1699), Independent divine, was born on Aug. 11, 1673, at Stepney, London. He studied at Utrecht and Leyden and in 1695 he graduated in philosophy and physics at Padua. In 1696 he returned to London. His *Mechanical Account of Poisons* appeared in 1702, and in 1703 he was admitted to the Royal Society, to whose *Transactions* he contributed in that year a paper on the parasitic nature of scabies. In the same year he was elected physician to St. Thomas's hospital. On the death of John Radcliffe in 1714, Mead became the recognized head of his profession; he attended Queen Anne on her deathbed, and was physician to George II. He died in London on Feb. 16, 1754.

See T. Lemon, *Memoirs of Richard Mead* (1755).

MEAD, WILLIAM RUTHERFORD (1846–1928), American architect, brother of Larkin Goldsmith Mead, was born at Brattleboro, Vt., on Aug. 20, 1846. After graduating from Amherst college in 1867, he studied with Russell Sturgis in New York, and then in Europe for two years. Since 1879 he has been a member of the firm of M'Kim, Mead and White, architects of the Boston public library, Columbia university, College of the City of New York, U.S. post office and municipal office buildings, New York city; Brooklyn Institute of Arts and Sciences, Bank of Montreal, and many other well-known university and metropolitan buildings. Mead is (1928) president of the American academy in Rome. He has been awarded the gold medal of honour of the National Institute of Arts and Letters, and in 1922 was made a Knight Commander of the Crown of Italy. He died in Paris, June 30, 1928.

MEAD. The name of a drink made by the fermentation of honey mixed with water. Alcoholic drinks made from honey were

common in ancient times, and during the middle ages throughout Europe. The Greeks and Romans knew of such under the names of *ὑδρόμελι* and *hydromeli; mulsum* was a form of mead with the addition of wine. The word is common to Teutonic languages. "Metheglin," an adaptation of the Welsh *meddyglyn*, means "spiced or medicated drink," and is not etymologically connected with "mead."

MEADE, GEORGE GORDON (1815–1872), American soldier, was born of American parentage at Cadiz, Spain, on Dec. 31, 1815. He graduated from West Point in 1835, and served in Florida against the Seminoles. Resigning from the Army in 1836 he became a civil engineer and constructor of railways, and was engaged under the war department in survey work, until 1842 when he re-entered the army as second-lieutenant in the corps of the topographical engineers. In the war with Mexico he was on the staffs successively of Gens Taylor, J. Worth and Robert Patterson, and was breveted for gallant conduct at Monterey. Until the Civil War he was engaged in various engineering works, mainly in connection with lighthouses, and later as a captain of topographical engineers in the survey of the northern lakes.

In 1861 he was appointed brigadier-general of volunteers, and had command of the 2nd brigade of the Pennsylvania reserves in the Army of the Potomac, under Gen. McCall. Receiving a severe wound at the action of Frazier's Farm, he was absent from his command until the second battle of Bull Run, after which he obtained the command of his division. He distinguished himself at the battles of South Mountain and Antietam, also at Fredericksburg he and his division won great distinction by their attack on the position held by Jackson's corps, and Meade was promoted to the rank of major-general of volunteers. Soon afterwards he was placed in command of the V. Corps. At Chancellorsville he displayed great intrepidity and energy, and on the eve of the battle of Gettysburg was appointed to succeed Hooker. In the famous three days' battle he inflicted a complete defeat on Gen. Lee's army. His reward was the commission of brigadier-general in the regular army. In the autumn of 1863 a war of manoeuvre was fought between the two commanders, on the whole favourably to the Union arms.

Grant, commanding all the Armies of the United States, joined the Army of the Potomac in the spring of 1864, and remained with it until the end of the war; but he continued Meade in his command, and successfully urged his appointment as major-general in the regular army (Aug 18, 1864). After the war Meade commanded successively the military division of the Atlantic, the department of the East, the third military district (Georgia and Alabama) and the department of the South. He died at Philadelphia on Nov. 6, 1872.

See I. R. Pennypacker, *General Meade* ("Great Commanders" series, 1901).

MEADOW BEAUTY (RHEXIA VIRGINICA)

MEADOW BEAUTY (*Rhexia virginica*), a North American plant of the melastoma family (Melastomaceae), called also deer-grass and Handsome Harry, native to sandy marshes from Maine to Ontario and Iowa and southward to Florida and Texas. It is a rather stout, squarish-stemmed perennial about a foot high, with smooth, oval, light green, three-ribbed, somewhat pointed leaves, and handsome purplish-magenta flowers, 1 in. to 1½ in. wide, blooming about midsummer. The floral parts consist of an urn-shaped calyx with a four-lobed limb; four broad, rounded petals; eight stamens with golden anthers; and a single pistil with a four-celled ovary, which develops into a four-valved many-seeded pod (capsule). The pistil protrudes beyond the anthers, thereby ensuring cross-fertilization, which is effected by honey-bees and other insects. In the Southern States there are several allied species, among which are the Maryland (*R. mariana*) and the ciliate meadow beauty (*R. ciliosa*).

MEADOWLARK (*Sturnella magna*), a well-known North American bird which, like the skylark (*Alauda arvensis*) of Europe, frequents meadows and sometimes sings on the wing. It is about 11 in. long, with brown back, yellow breast and black throat. The meadowlark is not related to the true larks, which are represented in America by the horned lark (*Otocoris alpestris*), but is an aberrant member of the American family Icteridae, which includes the blackbirds and orioles of that continent. The meadowlark has a musical whistle of three notes. It inhabits eastern North America southward to northern South America, but is replaced in the west by the allied western meadowlark (*S. neglecta*), which has a much richer and more varied song.

MEADVILLE, a city of north-western Pennsylvania, U.S.A., the county seat of Crawford county; on French creek and Federal highways 19 and 322, and served by the Bessemer and Lake Erie and the Erie railways, interurban trolleys and motor-bus lines. Pop. (1920) 14,568; 16,698 in 1930. It is the seat of Allegheny college (Methodist Episcopal; 1815) and the Pennsylvania college of music; is the commercial centre of a fertile agricultural region, in which there is also found natural gas; and has extensive railroad shops and various other manufacturing industries, with an output in 1925 valued at $10,070,046. There are wild and rugged ravines of great beauty near the city, and it is surrounded by the foot-hills of the Alleghenies. Meadville is the oldest settlement in north-western Pennsylvania. It was founded by David Mead in 1793 as a fortified post, laid out as a town in 1795, incorporated as a borough in 1823 and chartered as a city in 1866.

MEAGHER, THOMAS FRANCIS (1823–1867), Irish revolutionary leader, orator and American soldier, was born in Waterford, Ireland, on Aug. 3, 1823. He graduated at Stonyhurst college, Dublin. He became a member of the Young Ireland Party in 1845, and in 1847 was one of the founders of the Irish Confederation. In July 1848, the confederation created a "war directory" of five, of which Meagher was a member, and he and William Smith O'Brien travelled through Ireland arousing the countryside for a revolution against English rule. The attempt of 1848 proved abortive; Meagher was arrested in August, and in October was tried for high treason before a special commission at Clonmel. He was found guilty and was condemned to death, but his sentence was commuted to life imprisonment in Van Diemen's Land, whither he was transported in the summer of 1849. Early in 1852 he escaped, and in May reached New York city. He made a tour of the cities of the United States as a popular lecturer, and then studied law and was admitted to the New York bar in 1855. He found himself a leader of the Irish element in New York city and edited several influential Irish journals. At the outbreak of the Civil War he was made captain of a company (which he had raised) in the 69th Regiment of New York volunteers and fought at the first battle of Bull Run; he then organized an Irish brigade, of whose first regiment he was colonel until Feb. 3, 1862, when he was appointed to the command of this organization with the rank of brigadier-general. He took part in the siege of Yorktown, the battle of Fair Oaks, the seven days' battle before Richmond and the battles of Antietam, Fredericksburg, where he was wounded, and Chancellorsville, where his brigade was reduced in numbers to less than a regiment, and Gen. Meagher resigned his commission. On Dec. 23, 1863 his resignation was cancelled, and he was assigned to the command of the military district of Etowah, with headquarters at Chattanooga. At the close of the war he was appointed by President Johnson secretary of Montana Territory, and there, in the absence of the territorial governor, he acted as governor from Sept. 1866 until his accidental death in the Missouri river near Fort Benton, Mont., on July 1, 1867. Meagher's championship of President Johnson's principles of reconstruction and his religion made him unacceptable to the powerful vigilante organization which then ruled Montana, and in his efforts to dislodge the vigilantes from control he was unsuccessful.

See M. Cavanaugh, *Memoirs of General Thomas Francis Meagher* (1892); *Meagher of the Sword* (ed., A. Griffith, 1916); C. J. Bowers, *The Irish Orators* (1916).

MEALYWING, the name applied, from the white, powdery secretion with which they are covered, to about 50 species of small insects comprising the family *Coniopterygidae*. In these

forms, which are the smallest and most aberrant members of the order Neuroptera (*q v.*), the hind-wings are much reduced in size. They are decidedly beneficial to man, since their larvae feed on aphides, scale-insects, etc. About six species occur in Great Britain and the same number in the United States.

MEAN. The adjective "mean" is chiefly used in the sense of "average," as in mean temperature, mean birth or death rate, etc.

In astronomy (*q.v.*) the "mean sun" is a fictitious sun which moves at a uniform rate in the celestial equator and has its right ascension always equal to the sun's mean longitude. The time recorded by the mean sun is mean-solar or clock time; it is regular as distinct from the non-uniform solar or sun-dial time. The "mean moon" is a fictitious moon which moves around the earth with a uniform velocity and in the same time as the real moon. The "mean longitude" of a planet is the longitude of the "mean" planet, *i.e.,* a fictitious planet performing uniform revolutions in the same time as the real planet.

Mean in Mathematics.—The term "mean," in its most general sense, is given to some function of two or more quantities which (1) becomes equal to each of the quantities when they themselves are made equal, and (2) is unaffected in value when the quantities suffer any transpositions. The three commonest means are the arithmetical, geometrical and harmonic; of less importance are the contraharmonical, arithmetico-geometrical and quadratic.

The arithmetical mean of n quantities is the sum of the quantities divided by their number n. The geometrical mean of n quantities is the nth root of their product. The harmonic mean of n quantities is the reciprocal of the arithmetical mean of their reciprocals. The significance of the word "mean," *i.e.,* middle, is seen by considering 3 instead of n quantities; these will be denoted by a, b, c. The arithmetic mean b, is seen to be such that the terms a, b, c are in arithmetical progression, *i.e.,* $b=\frac{1}{2}(a+c)$; the geometrical mean b places a, b, c in geometrical progression, *i.e.,* in the proportion $a : b :: b : c$ or $b^2=ac$; and the harmonic mean places the quantities in harmonic proportion, *i.e.,* $a : c :: a-b : b-c$, or $b=2ac/(a+c)$. The contraharmonical mean is the quantity b given by the proportion

$$a : c :: b-c : a-b, \text{ i.e., } b=(a^2+c^2)/(a+c).$$

The arithmetico-geometrical mean of two quantities is obtained by first forming the geometrical and arithmetical means, then forming the means of these means, and repeating the process until the numbers become equal. They were invented by Gauss to facilitate the computation of elliptic integrals. The quadratic mean of n quantities is the square root of the arithmetical mean of their squares.

MEANING. Speaking broadly any thing or action which suggests another without actually being a picture or copy of it may be said to have meaning. In so far as it has meaning it is called a mark or a sign or a symbol. A portrait depicts a person, a picture depicts a landscape, but neither "means" its original in the way in which their names or descriptions (or other symbols) do. Anything might be made the symbol of another either by purely arbitrary association or by some more natural association based on objective connections. In one or other of these ways the Union Jack has become the symbol of the British empire, Stars and Stripes, of the United States; the giving of a ring is the symbol of engagement or of marriage; the lily is the symbol of purity; rosemary of sweet remembrance; and so on. Some things are actually called after what they symbolize or mean rather than after what they are in themselves—"forget-me-nots," for example. Other things are called by names which are descriptive partly of what they are, and partly of what they symbolize—*e.g.,* "marriage ring," "loving cup." In so far as the labours of science and of art reach beyond observation and description they are mainly concerned with discovering the meanings of things. But the meanings sought by the man of science may not be those which the poet looks for. And there may have been some scientific virtue and restraint in the man of whom Wordsworth hummed rather plaintively:

> The primrose by the river's brim
> A yellow primrose was to him,
> And it was nothing more.

Meaning is the creation of thought. All sorts of things, including all sorts of sounds and forms, might exist even if there were no thinking beings; but in the absence of thinking beings they could only be what they are, they could not *mean* anything else, they could not serve as symbols. Symbols are only symbols for thought—the thought which reads in one thing the reference to another. In fact, concepts and ideas, which are the very stuff of all thought, are just meanings or apprehensions of meaning.

Language, of course, is the most familiar, most useful, and most potent system of symbols. And the problems of meaning have been studied chiefly in connection with language. In logic it is customary to distinguish the different kinds of meaning which terms may have. The most important distinctions are the following: (a) *The meaning of a term in extension* (or its application) consists of the objects to which it is applicable; and one may be said to know this more or less if, as frequently happens, one can apply the term correctly even if he cannot define it adequately. (b) *The meaning of a term in intension* (or its signification) consists of any quality or characteristic which the term suggests. One may distinguish between the *variable intension* of a term, in so far as it may suggest different qualities to different people, from *standard* (or conventionally fixed) *intension* (or connotation), which is more or less the same for all who use the language correctly; and both may be distinguished from *complete or comprehensive intension* or the totality of qualities, etc., which the term would suggest to one who had a complete knowledge of the things which the term denotes (or means in extension). Sometimes the term "meaning" is used as synonymous with "significance." But "significance" unlike "signification" has reference to *value* rather than to *meaning*. Occasionally "meaning" is also used instead of "intention" or "purpose."

See J. N. Keynes, *Formal Logic* (1910); C. K. Ogden and I. A. Richards, *The Meaning of Meaning* (1927); Lady V. Welby, *What is Meaning?* (A. Wo.)

MEASLES (*Morbilli, Rubeola*), an acute infectious disease occurring mostly in children, and possibly caused by a filter-passing virus (*q.v.*). The course of the disease is as follows. After exposure to infection, for from eight to twelve days there is an incubation period unaccompanied by evident symptoms. Then follows the sudden onset of acute catarrh of the mucous membranes. Minute white spots in the buccal mucous membrane frequently occur, and are diagnostic if present. Sneezing, a watery discharge, sometimes bleeding, from the nose, redness and watering of the eyes, dry, noisy cough, hoarseness, and occasionally sickness and diarrhoea, characterize this stage. With these, fever (102°–104° F), abating after the second day, rapid pulse, headache, thirst and restlessness are usually present. In young children, convulsions may usher in, or occur in the course of, this stage, which lasts for four or five days. On the fourth or fifth day after the invasion, the characteristic eruption appears on the skin, being first noticed on the brow, cheeks, chin, behind the ears and on the neck. It consists of small dusky red or crimson spots, slightly elevated above the surface, at first isolated, but tending to become grouped into patches of irregular, occasionally crescentic, outline, with portions of skin free from the eruption intervening. The face acquires a bloated appearance, which, taken with the catarrh, renders diagnosis at this stage a matter of no difficulty. The eruption spreads downwards over the body and limbs, which are soon thickly studded with the red spots or patches. Sometimes these become confluent over a considerable surface. The rash continues to come out for two or three days, and then begins to fade in the order in which it first showed itself, namely from above downwards. About a week after its first appearance nothing remains beyond a faint staining of the skin. Usually during convalescence slight, branny desquamation occurs. At the commencement of the eruptive stage the fever, catarrh, etc., become aggravated, the temperature often rising to 105° or more, and red patches similar to those on the surface of the body may be observed on the throat. These symptoms usually decline when the rash has attained its maximum, the temperature falling suddenly. In favourable cases convalescence is rapid.

Measles may, however, occur in a very malignant form, the

rash being feebly developed, and dark purple, while there is great prostration with intense catarrh of the respiratory or gastro-intestinal mucous membrane. Such cases occur mostly in circumstances of bad hygiene or in isolated communities that have long been free from epidemics of measles. On the other hand, cases of measles are often so mild that other treatment than a few days in bed is unnecessary.

Measles derives its chief importance from the risk of pulmonary complications. These are most frequent in the colder seasons of the year and in very young and delicate (particularly, rickety) children. Under these conditions the catarrh instead of abating, advances, and broncho-pneumonia (*see* BRONCHITIS, PNEUMONIA) supervenes. By far the greater proportion of the mortality in measles is due to this complication. Or there may remain as direct results of the disease chronic ophthalmia, or discharge from the ears with deafness, and occasionally a form of gangrene affecting the tissues of the mouth or cheeks and other parts of the body, leading to disfigurement and gravely endangering life.

Apart from those immediate risks there may remain after measles a weakened condition of the general health, which paves the way for subsequent tuberculosis.

Measles is a disease of the earlier years of childhood, though not unknown in nurslings or infants under six months old. It is rare in adults, since an attack in childhood mostly confers immunity for the rest of life. All races of men appear liable, and when a community has long been immune from outbreaks introduction of infection is followed by a devastating epidemic. Thus in Fiji in 1875 it was estimated that about one-fourth of the inhabitants died within three months.

In many lands, such as the United Kingdom, measles is rarely absent from large centres of population, and from time to time epidemics arise among those who have not been protected by a previous attack. The risk of conveying infection is greatest during the catarrhal stage before the rash appears. Hence the difficulty of timely isolation, and the readiness with which the disease is spread in schools and families. While contagion is generally direct, it can also be conveyed by particles from the nose and mouth which, after being expelled by coughing or sneezing are deposited on clothes, toys, etc.

Treatment.—The treatment embraces isolation of the sick to the fullest possible extent and at as early a period as possible. Epidemics have often been curtailed by such a precaution. The unaffected children in a family should be kept from school for three weeks from the latest possible date of infection, and all clothing in contact with the patient or nurses should be disinfected. In extensive epidemics it is often necessary to close the schools for a time. As regards medical treatment, in an ordinary case of measles little is required beyond what is necessary in febrile conditions generally. The serious complications call for special measures (*see* BRONCHITIS; PNEUMONIA; etc.). During convalescence the patient must be guarded from exposure to cold. Serum from a convalescent case of measles contains sufficient anti-body to be used as a preventive; 5 to 10 cc. when injected subcutaneously into an infant when the exposure has not lasted for more than six days will either prevent the disease or greatly lessen its severity. Thirty cc. of blood from a person who has had measles in childhood equals 5 cc. of convalescent serum.

"German measles" (*Rötheln,* or *Epidemic Roseola*) is a contagious eruptive disorder resembling both measles and scarlet fever, but exhibiting its distinct individuality in protecting from neither. It occurs most commonly in children, and is occasionally seen in extensive epidemics. Beyond isolation, no special treatment is called for. The disease is often mistaken for true measles, and many of the alleged second attacks of the latter malady are probably cases of rötheln. The chief points of difference are the following: (1) the stage of invasion, which in measles lasts four days and is accompanied by fever and catarrh, in rötheln is either absent or slight, and lasts only for one day. (2) The eruption of rötheln, although as regards its locality and manner of progress similar to measles, differs in appearance, the spots being smaller, paler and with less tendency to grouping in crescentic patches. The rash attains its maximum in about one day, and quickly disappears. There is not the same increase of temperature in this stage as in measles. (3) White spots on the buccal mucous membrane, found in measles, do not occur in rötheln. (4) The milder character of rötheln throughout its whole course, and the absence of complications.

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MEASUREMENT. The determination of the magnitude of anything in terms of a suitable unit. Such units may be quite arbitrary, *e.g.,* the pound, foot, second or degree centigrade, or may be derived from a combination of the arbitrary units, *e.g.,* pounds per cubic foot. The procedure adopted depends entirely on the nature of the quantity to be measured and on the accuracy required. Details will be found in the article on METROLOGY.

MEASURES AND WEIGHTS. This subject may be most conveniently discussed under two headings—I. Scientific and II. Commercial. The scientific basis of the systems of units employed is also dealt with in the article PHYSICAL UNITS and the unit of TIME is discussed in the article bearing that title.

I. SCIENTIFIC

1. In Great Britain, the Irish Free State, Northern Ireland and the United States of America two systems of weights and measures are now recognized—the imperial and the metric. The fundamental units of these systems are—of length, the yard and the metre; and of mass, the pound and the kilogram. The term "weight" denotes a magnitude of the same nature as a force; the weight of a body is the product of the mass of the body by the acceleration of gravity, a quantity which varies with the locality in which it is measured. (*See* MECHANICS.) The normal weight of a body is the product of the mass of the body by the normal acceleration of gravity, the value adopted for this latter quantity by the Comité International des Poids et Mesures (C.I.P.M.) at Paris being 980·665 cm./sec.^{2}.

2. **The Metric System.**—The standards of the International Metric System are fixed by an International Conference on Weights and Measures established by a treaty—the Convention du Mètre—signed in Paris on May 20th, 1875. This treaty created an International Bureau, which was built at Sèvres on a piece of land declared by the French Government to be international property, and governed by an International Committee (C.I.P.M.). (See *La Creation du Bureau International des Poids et Mesures* by its Director, Dr. Ch.-Ed. Guillaume.) The international prototype standards are kept at Sèvres, and copies have been made to serve as national standards for the 31 Governments which subscribe to the treaty.

The Conference meets once every six years and, at its seventh meeting in 1927, the metre (*Mètre-à-traits*) was defined:—

> The unit of length is the metre, defined by the distance at the temperature of melting ice between the centres of two lines traced on the platinum-iridium bar deposited at the International Bureau of Weights and Measures, and declared prototype of the metre by the first general conference on weights and measures, this bar being subjected to normal atmospheric pressure and supported by two rollers, at least 1 centimetre diameter, situated symmetrically in the same horizontal plane and at a distance of 572 millimetres from each other.

This metre (m.) (fig. 1) is the only unit of metric extension by which all other metric measures of extension, whether linear, or superficial, are ascertained.

The legal definition does not now refer to any natural standards or to physical constants, though originally the metre (*mètre-des-archives*) was intended to be one ten millionth part of the quadrant of the earth's meridian. It has, however, been shown by A. A. Michelson that a standard of length might be restored, if necessary, by reference to the measurement of wave-lengths of light

(*see* INTERFEROMETER), and the Conference decided (1927) to adopt as an alternative and provisional definition of the metre 1,553,164·13 of the wave lengths of the red light emitted by a cadmium vapour lamp excited under certain specified conditions. The relative accuracy of the value of the metre in terms of light waves is one part in ten millions.

The international prototype kilogram (kg.) is a cylinder of platinum, alloyed with 10 per cent. of iridium, of approximately equal height and diameter. Originally the kilogram was intended to be the mass of a cubic decimeter of water at its temperature of maximum density, 4° C. All other metric weights, and all measures having reference to metric weight are referred to secondary standards in Great Britain and the United States.

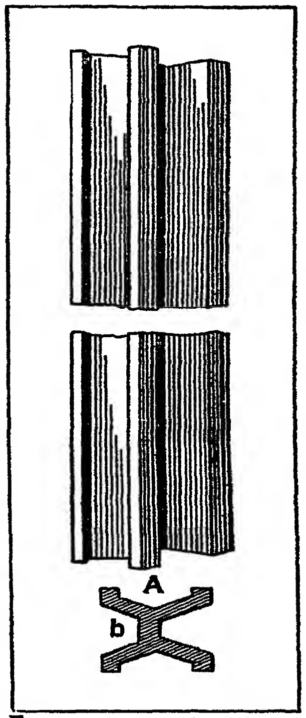

FIG. 1.—NATIONAL STANDARD METRE, 1897
Iridio-platinum bar of Tresca section as shown at A. The two microscopic lines are engraved on the measuring axis of the bar at "b," one near each end

The international unit of volume in the metric system is the volume occupied by the mass of 1 kilogram of pure water at its maximum density and under normal atmospheric pressure; this volume is known as a *litre* (l). (Normal atmospheric pressure is the pressure exerted by a column of mercury 76cm. high at the temperature of melting ice and at a place where gravity has its standard value. The density of mercury at 0° C. is 13·5951 g. per cu.cm. so that normal atmospheric pressure $=76\times13{\cdot}5951\times980{\cdot}665 = 1{\cdot}013250\times10^6$ dynes per sq.cm. (Atmospheric pressure at latitude 45° differs from the above in that the gravitational acceleration is taken as 980·616 cm./sec.^{2}) An elaborate investigation at the International Bureau has shown the volume of the litre to be 1·000027 cubic decimetres (*Travaux et Mémoires du Bureau International*, 1910, tome XIV). In determinations of volume which do not admit of a high degree of accuracy the cubic decimetre can be taken as equivalent to the litre.

In Great Britain and Northern Ireland the metric standard of capacity is the litre, represented (Order in Council, May 19, 1890) by the capacity of a hollow cylindrical brass measure whose internal diameter is equal to one-half its height, and which at 0° C., when filled to the brim, contains one kg. of distilled water of the temperature of 4° C., under an atmospheric pressure equal to 760 millimetres at 0° C. at sea-level and latitude 45°; the weighing being made in air, but reduced by calculation to a vacuum. In such definition an attempt has been made to avoid former confusion of expression as to capacity, cubic measure, and volume; the litre being recognized as a measure of capacity holding a given weight of water.

3. **The British System.**—The imperial standard yard is defined (Weights and Measures Act, 1878) as the distance, at 62·00° F, between two fine lines engraved on gold studs sunk in a bronze bar. This bar was cast by Troughton & Simms in 1844.

Recent comparisons by the National Physical Laboratory (N.P.L.) show that this 1878 yard=0·9143987m.; the present legal equivalent of the yard in the metric system is 0.914399 m., a value which makes 1 inch=2·54 cm. correct to 1 part in a million (*International Critical Tables* (I.C.T.), Vol. 1. p. 7).

The imperial standard pound avoirdupois is a cylinder of pure platinum about 1·35 in. high and 1·15 in. diameter (fig. 3). The grain is one seven thousandth part of this pound and the troy pound is equivalent to 5,760 grains. The standard pound is 0·45359243 kg.

The standard gallon is the volume of 10 lb. avoirdupois of pure water as weighed in air against brass weights, the temperature of the air and the water being 62° F., and the barometric pressure 30 in. of mercury. This legal definition is incomplete in that it does not state the density of the brass weights; in official comparisons the density is taken to be 8·143 g. per cu.cm. Legally the gallon is equivalent to 4·5459631 l (*see* para. 5). The fluid ounce (apothecaries' measure) has a volume of $\frac{1}{20}$ pint ($\frac{1}{160}$ gal.) thus 16 fluid ounces of pure water weigh 1 pound (avoirdupois).

In the measurement of the cubic inch it has been found (*Proc. Roy. Soc.*, 1895, p. 143) that the mass of a cubic inch of distilled water freed from air, and weighed in air against brass weights (density=8·13), at the temperature of 62° F, and under an atmospheric pressure equal to 30 in. (at 32° F), is equal to 252·297 grains weight of water at its maximum density (4° C). Hence a cubic foot of water would weigh 62·281 lb. avoir., and not 62·321 lb. as at present legally taken.

The imperial standard measure of capacity is a hollow cylinder (fig. 4) made of brass, with a plane base, of equal height and diameter; which when filled to the brim, as determined by a plane glass disc, contains 10 lb. weight of water at 62° F weighed in air against brass weights, when the barometric pressure is 30 in. A secondary standard measure for dry goods is the bushel of 1824, containing 8 imperial gallons, represented by a hollow bronze cylinder having a plane base, its internal diameter being double its depth. It may be noted that the term "Imperial" first occurs in the Weights and Measures Act of 1824.

In the United States the fundamental units of the national system are defined in terms of the metric system, and originated from British standards which, in some cases, have been altered since the original U.S. legislation was passed (*Dictionary of Applied Physics* [D.A.P.], vol. iii., p. 594; I.C.T., vol. i., p. 13). Thus the United States unit of capacity, the gallon, is the old Queen Anne gallon and is equal to 231 cu. in., or 3·785 l. The U.S. pound is the same as the British pound, and the U.S. yard ($\frac{3600}{3937}$m.) is about 3 parts in a million greater than the British yard.

4. **Materials.**—The Matthey alloy iridio-platinum (90% platinum, 10% iridium) is probably of all substances the least affected by time or circumstance and it is therefore used for the prototype metre and kilogram. It is very costly and though its coefficient of linear expansion (8.7×10^{-6} per deg. C) is small, it is not negligible, hence ordinary length standards are often made of Guillaume's alloy (invar) of nickel (35.7%) and steel (64.3%). This metal can be highly polished and is capable of receiving fine graduations. Its coefficient of expansion is very small—only 0.9×10^{-6} per deg. C. There appears to be some objection to the use of iridio-platinum for weights, as, owing to its great density (21·57 g. per cu.cm.) the slightest abrasion will make an appreciable difference in weight; sometimes, therefore, quartz or rock-crystal is used; but to this also there is some objection, as, owing to its low density (2.65 g. per cu.cm.) the exposed surface is unduly large and a large buoyancy correction is necessary. For small standard weights platinum (density=21.45) and aluminium (density=2·67) are used, and also an alloy of palladium (60%) and silver (40%) (density=11.00).

Ordinary weights, whether lacquered or plated with gold or platinum frequently gain in weight for years without any visible alteration and lacquered weights are liable to vary with large variations in the humidity of the air (for example by 0·2 mg. per 100 g.).

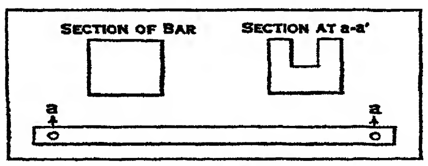

FIG. 2.—PRESENT IMPERIAL STANDARD YARD, 1844

5. **Effects of Temperature and Pressure.**—The graduations on the imperial standard yard (fig. 2) are sunk below the surface of the bar, partly to protect them from damage, but chiefly so that they may lie in the plane of the neutral axis of the bar. The Tresca section of the prototype metre (fig. 1) gives these advantages and, in addition, (*a*) renders it possible to graduate the bar along the whole of its length, and (*b*) gives great strength for the weight of metal used.

The variation in the length of a metal bar with temperature makes it necessary to define the temperature at which standards involving extension are to be used. The choice of 0° C by the

C.I.P.M. as the temperature at which the prototype metre is to be used makes this temperature definite and independent of the vagaries of any thermometric substance, but it is exceedingly inconvenient for industrial standards. For such purposes scales and gauges are frequently adjusted to be standard at 20° C (*e.g.*, in the United States).

The Fahrenheit scale is still used for imperial standards and the temperature selected 62° F (16·667° C) is much more convenient than 0° C for workshop use. At the time of the construction of the imperial standards in 1844, Sheepshanks's Fahrenheit thermometers were used; but it is difficult to say now what the true temperature then, of 62° F, may have been as compared with 62° F of the present normal hydrogen scale.

The influence of the variation of atmospheric pressure on standards of length is very small. A change in atmospheric pressure from 29 to 31 in would cause the length of the prototype metre (fig. 1) to alter by 0·000048 mm., and the standard yard (fig. 2) by 0·000002 in.

When masses are compared by means of their weights allowance must be made for the buoyant effect of the air. This is equal to the density of the air times the volume of the body and therefore varies with the pressure, temperature and humidity of the air in the balance case. It follows that definitions which involve comparisons of the weights of bodies of different densities are not complete unless these atmospheric conditions are specified together with the densities of the materials to be employed. Most weights are marked by their makers in terms of the brass weights which balance them in air. For precision work such weights must be calibrated against a standard whose "weight in vacuo" is known.

If m_0 be the mass of the body weighed and ρ_0 its density; m the true mass of the weights used to counterpoise it on an equal arm balance, ρ the density of these weights and σ the density of the air, then $m_0 - \frac{m_0}{\rho_0}\sigma = m - \frac{m}{\rho}\sigma$ or with sufficient accuracy for most purposes (but not for weighing gases) $m_0 = m + m\left(\frac{1}{\rho_0} - \frac{1}{\rho}\right)\sigma$. The first equation may be used to calculate the relation between the litre and the imperial gallon. In that case $m = 10$ lb $=$ 4·5359243 kg.; ρ the density of brass is taken to be 8·143 g. per cu cm. (para. 3); ρ_0 = density of water at 62° F = 0·99886II g. per cu cm. and σ, the density of air = 0·001218738 g per cu cm. —a value obtained by supposing the air to contain 4 volumes in 10,000 of carbon dioxide; to be at a temperature of 62° F, and at the pressure exerted by a column of mercury 30 inches high at 62° F in London, where the value of g = standard value (lat. 45°) × 1·000577. Substituting for m, ρ_0, ρ and σ gives $m_0 = 4{\cdot}5407857$ kg., whence 1 gallon $= m_0/0{\cdot}99886II = 4{\cdot}5459631$ litres. It must be realized that this calculation gives the legal equivalent, the last two figures, at least, have no experimental justification.

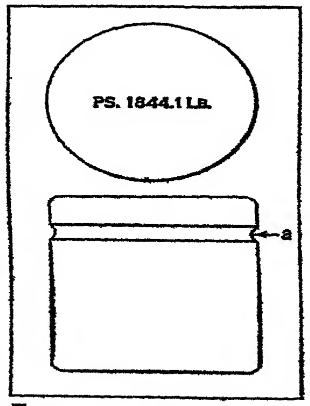

FIG. 3.—IMPERIAL STANDARD POUND, 1844
Platinum pound avoirdupois, of cylindrical form, with groove at "a" for lifting

6. National Standards and Standardizing Institutions.—In all countries the national standards of weights and measures are in the custody of the State, or of some authority administering the government of the country. An act of 1866 placed the imperial and metric standards of the British Empire in the custody of the Board of Trade and, under the direction of a Royal Commission on Standards, a Standards Department of the Board was developed in 1870 to conduct all comparisons and other operations with reference to weights and measures which it might be the duty of the State to undertake (*e.g.*, the comparison of standards used by Inspectors of Weights and Measures). Similar standardizing offices are established in other countries. (*See* STANDARDS.) Verified "Parliamentary Copies" of the imperial standards are placed at the Royal Mint, with the Royal Society, at the Royal Observatory and in the Palace of Westminster. Besides the State departments dealing with weights and measures there are other standardizing institutions. In Germany the Physikalisch-Technische Reichsanstalt at Charlottenburg was established in 1887 under Herman von Helmholtz as a national testing and research institution. In England the National Physical Laboratory at Teddington, Middlesex, was formed in 1900. Here all kinds of measuring instruments used in industry are standardized, physical constants determined and materials tested. In the United States similar work is performed by the National Bureau of Standards, Washington, established in 1901; and, in France, by the Laboratoire d'Essais Méchaniques, Physiques, Chimiques, et de Machines, controlled by the Conservatoire National des Arts et Métiers.

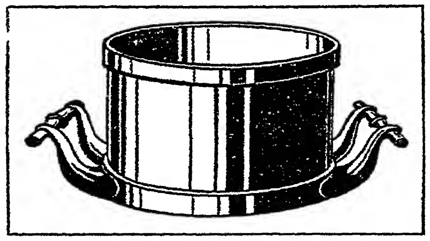

FIG. 4.—PRESENT IMPERIAL STANDARD GALLON, 1824

National standards committees or associations also exist in some twenty countries. Of these the oldest is the British Engineering Standards Association (B.E.S.A.) originally formed in 1901 by the Institutions of Civil, Mechanical and Electrical Engineers, the Institute of Naval Architects, and the Iron and Steel Institute. The American Standards Association was formed in 1917 and, following a conference in New York in 1926, an International Standards Association was set up with Sir Richard Glazebrook as first president.

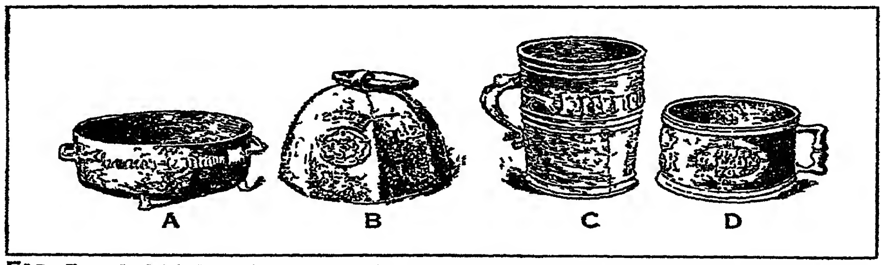

FIG. 5.—A. WINCHESTER BUSHEL OF HENRY VII; B. STANDARD HUNDREDWEIGHT (112 LB.) OF ELIZABETH; C. ALE GALLON OF HENRY VII; D. THE OLD WINE GALLON

7. **Ancient Standards of England and Scotland.**—A "troy pound" and a new standard yard, as well as secondary standards, were constructed by direction of parliament in 1758–1760, and were deposited with the Clerk of the House of Commons. When the Houses of Parliament were burned down in 1834, the pound was lost and the yard was injured. The injured standard was then lost sight of, but it was in 1891 brought to light by the Clerk of the Journals, and has now been placed in the lobby of the residence of the Clerk of the House, together with a standard "stone" of 14 lb. (*Report on Standards deposited in the House of Commons*, Nov. 1, 1891.)

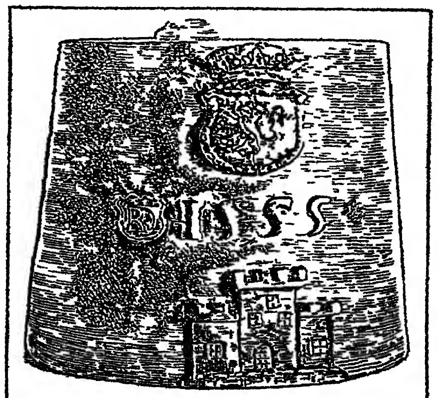

FIG. 6.—THE SCOTS CHOPPIN OR HALF-PINT, 1555

In the measurement of liquids the old "wine gallon" (231 cu. in.) was in use in England until 1824, when the present imperial gallon (fig. 4) was legalized; and the wine gallon of 1707 is still referred to as a standard in the United States. Together with the more ancient standard of Henry VII. and of Queen Elizabeth, this standard is deposited in the Jewel Tower at Westminster. They are probably of the Norman period, and were kept in the Pyx Chapel at Westminster, now in the custody of the Commissioners of Works. A sketch of these measures is given in fig. 5. (S. Fisher, *The Art Journal*, Aug. 1900.)

Besides these ancient standards of England (1495, 1588, 1601)

there are at the council chambers of Edinburgh and Linlithgow some of the interesting standards of Scotland, as the Stirling jug or Scots pint, 1618; the choppin or half-pint, 1555 (fig. 6); the Lanark troy and tron weights of the same periods (fig 7). (Buchanan, *Ancient Scotch Standards*)

English Weights and Measures Abolished.—The yard and handful or 40 in ell, abolished in 1439 The yard and inch, or 37in. ell (cloth measure), abolished after 1553; known later as the Scotch ell = 37 06. Cloth ell of 45 in , used till 1600 The yard of Henry VII = 35·963 in Saxon moneyers pound, or Tower pound, 5400 grains, abolished in 1527. Mark, ⅔ pound = 3600 grains. Troy pound in use in 1415, established as monetary pound 1527. Troy weight was abolished, from the 1st of January 1879, by the Weights and Measures Act 1878, with the exception only of the Troy ounce, its decimal parts and multiples, legalized in 1853, 16 Vict. c. 29, to be used for the sale of gold and silver articles, platinum and precious stones. Merchant's pound, in 1270 established for all except gold, silver and medicines = 6750 grains, generally superseded by avoirdupois in 1303. Merchant's pound of 7200 grains, from France and Germany, also superseded. ("Avoirdepois" occurs in 1336, and has been thence continued: the Elizabethan standard was probably 7002 grains) Ale gallon of 1601 = 282 cub. in., and wine gallon of 1707 = 231 cub. in., both abolished in 1824. Winchester corn bushel of 8 × 268·8 cub. in. and gallon of 274¼ are the oldest examples known (Henry VII.), gradually modified until fixed in 1826 at 277·274, or 10 pounds of water.

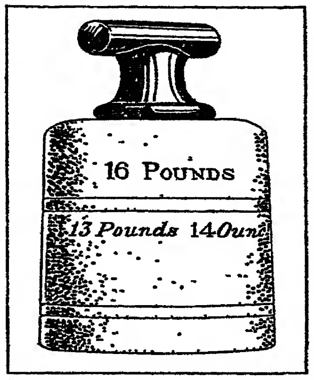

FIG 7—LANARK STONE TROY WEIGHT, 1618

French Weights and Measures Abolished.—Often needed in reading older works.

ligne, ·08883 in.	12 = pouce, 1·0658	12 = pied, 12·7892	6 = toise, 76·735	2000 = lieue de poste. 2·42219 miles.
grain, ·8197 gr.	72 = gros, 59·021	8 = once, 472·17	8 = marc, 3777·33	2 = poids de marc (or livre), 1·0792 lb.

Rhineland foot, much used in Germany, = 12·357 in = the foot of the Scotch or English cloth ell of 37·06 in , or 3 × 12·353.

II. COMMERCIAL

1. **Denominations.**—The denominations of trade weights and measures at present used in the United Kingdom are represented by "Board of Trade standards," by which are regulated the accuracy of the common weights and measures handled in shops, etc. (*Board of Trade Model Regulations,* 1892; Weights and Measures Acts, 1878, 1889, 1892, 1893.)

Imperial Measures of Length.—100 feet, 66 feet or a chain of 100 links, rod, pole, or perch, measures from 10 feet to 1 foot; 18 inches; yard of 36 inches, ½, ¼, ⅛, 1/16, yard, nail, inch, and duodecimal, decimal and binary parts of the inch.

Imperial Measures of Capacity.—Liquid measures from 32 gallons to 1 gallon, quart, pint, ½ pint, gill, ½ gill, ¼ gill. Dry measures of bushel, ½ bushel, peck, gallon, quart, pint, ½ pint.

Apothecaries' Measures.—40 fluid ounces to ½ fl. oz., 16 fluid drachms to ½ fl. dr., 60 minims to 1 minim.

Avoirdupois Weights.—Cental (100 lb), 56 lb (½ cwt.), 28 lb, 14 lb (stone), 7, 4, 2, 1 lb; 8, 4, 2, 1, ½ ounce (8 drams); 4, 2, 1, ½ drams.

Troy Weights.—The ounce (480 gr.) and multiples and decimal parts of the ounce troy from 500 ounces to 0 001 oz.

Apothecaries' Weights.—10 oz. to 1 oz. (480 gr.); 4 drachms to ½ oz.; 2, 1 drachms; 2 scruples to ½ scruple; and 6 grains to ½ grain.

Pennyweights.—20 dwt. (480 grains), 10, 5, 3, 2, 1 dwts.

Grain Weights.—4000, 2000, 1000 gr. (making 7000 gr. or 1 lb), 500 to 0 01 gr.

2. The international trade metric weights and measures (1897) handled in shops, etc., of which there are also Board of Trade standards, are set out as follows:—

Length.—Decametre or 10 metres; double metre; metre or 1000 millimetres; decimetre or 0·1 metre; centimetre or 0 01 metre; millimetre.

Capacity.—20 litres; 10 litres or decalitre; 5, 2, 1, 0·5, 0·2, 0·1 (decilitre); 0·05, 0·02, 0 01 (centilitre); 0 005, 0·002, 0 001 (millilitre) litres.

Cubic Measures.—1000 (litre), 500, 200, 100, 50, 20, 10, 5, 2 cubic centimetres, 1 c c. or 1000 cubic millimetres.

Weights—20, 10, 5, 2, 1 kilograms; 500 to 1 gramme; 5 to 1 decigram; 5 to 1 centigram; 5 to 1 milligram. (Series 5, 2, 2′, 1, *i e.* with a duplicate weight of "2.")

3 **Equivalents.**—The metric equivalents of the units of the metric system in terms of the imperial system, as recalculated in 1897, are as follows (*Metric Equivalents,* King's Printers, 1898):—

IMPERIAL TO METRIC

1 yard	=	0·914399 m.
1 square yard	=	0·836126 m².
1 cubic inch	=	16·387 c.c.
1 gallon	=	4·5459631 l.
1 pound (7000 grains)	=	0·45359243 kg.
1 ounce troy (480 gr.)	=	31·1035 grammes.
1 fluid drachm	=	3·552 millilitres (ml.)
1 fluid ounce	=	2·84123 centilitres (cl.).

METRIC TO IMPERIAL

1 metre (m.)	=	39·370113 inches.
1 square metre (m².)	=	10·7639 square feet.
1 cubic decimetre (c.d.) or 1000 cubic centimetres (c.c.)	=	61·024 cubic inches.
1 litre (l.)	=	1·7598 pints.
1 kilogram (kg.)	=	2·2046223 lb avoir.
1 gramme (g.)	=	15·4323564 grains or 0·7716 scruple.

The equivalents of the old Russian weights and measures, in terms also of the imperial and metric weights and measures, were recalculated in 1897 (*C.I.P M , Procès-verbaux* [1897], p. 155). The following are the leading equivalents:

1 Russian pound = { 0·025 pood. 96 zolotniks. 9216 dolis.
= 0·40951240 kg.
= 0·90282018 lb avoir.

1 arshin = { 0·00066 verst. 0·33 sagène. 16 verchoks. 280 liniias.
= 0·711200 metre
= 0·777778 yard.

1 vedro = { 10 shtoffs = 100 charkas
= 12·299 litres
= 2·7056 gallons.

1 chetvert = 8 chetveriks
= 2·0991 hectolitres
= 5·7719 bushels.

4. **Local Control.**—The necessary local inspection and verification of weights and measures in use for trade (as distinct from the verbal and written use of weights and measures) is in the United Kingdom undertaken by inspectors of weights and measures, who are appointed by the local authorities, as the county and borough councils. An inspector is required to hold a certificate of qualification, and for his guidance general regulations are made by his local authority as to modes of testing weights, measures and weighing instruments. In Europe the local inspection is generally carried out through the State, and a uniform system of local verification is thereby maintained.

5. **Errors.**—In the verification of weights and measures a margin of error is permitted to manufacturers and scale-makers, as it is found to be impossible to make two weights, or two measures, so identical that between them some difference may not be found either by the balance or the microscope. For common weights and measures this margin (tolerance, remedy or allowance, as it is also called) has been set out by the Board of Trade for all the various kinds of weights and measures in use for commercial purposes in the United Kingdom, and similar margins of error are recognized in other countries. For instance, on 1 lb. avoir. weight made of brass, 2 grains in excess are allowed; on 1 oz. troy or apothecaries' weight, +0·2 grain is allowed; on 1 pint pot, 4 fluid drachms is permitted; on 1 brass yard, 0·05 inch in excess or 0·02 inch in deficiency in length is allowed for ordinary trade purposes.

6. **Foreign Weights and Measures.**—Throughout the Brit-

ish Empire the imperial system of weights and measures is legal.

In Russia the use of metric weights and measures has been compulsory since Jan. 1, 1927.

In India the native weights, etc., ancient and arbitrary, are still followed. In 1889 the British yard was adopted for the whole of India (Measures of Length Act) at a normal temperature of 85° F as standardized to the imperial yard at 62° F. The metric system was also introduced, mainly for railway purposes, in 1870 and 1871 (Indian Acts). Certified measures of the yard, foot and inch are kept by the Commissioners of Police at Calcutta, Madras and Bombay.

In standardizing a weight for use in India, correction has to be made for the weight of air displaced by the material standard, and for such purpose the normal temperature of 85°, at atmospheric pressure 29·8 inches, latitude 22° 35′ 6·5″ (Calcutta), $g = g_{45^\circ} \times 0{\cdot}9982515$ is taken. The "tola" (180 grains) is properly the Government unit of weight for currency; and 80 tolas make the "Government seer."

7. **Customary Weights and Measures.**—In some districts of the United Kingdom, as well as in provincial districts of other countries, old local and customary denominations of weights and measures are still found to be in use, although their use may have been prohibited by law. So powerful is custom with the people.

8. **Legislation.**—In everyday transactions with reference to weights and measures, the British legislature also exercises control in industrial pursuits. For instance, in weighing *live* cattle, owners of markets are required to provide adequate accommodation. Useful statutes have also been passed to protect the working class, as in checking the weighing instruments used in mines in Great Britain, over which instruments wages are paid, and in the inspection of similar instruments used in factories and workshops. The Merchandise Marks Act 1887 makes it an offence also to apply in trade a false description, as to the number, quantity, measure, gauge or weight of goods sold; and this Act appears to reach offences that the Weights and Measures Acts may perhaps not reach.

9. **Pharmaceutical Weights and Measures.**—By the Medical Act of 1858 and the Act of 1862, the General Council of Medical Education and Registration of the United Kingdom are authorized to issue a "Pharmacopoeia" with reference to the weights and measures used in the preparation and dispensing of drugs, etc. The British Pharmacopoeia issued by the Council in 1898 makes no alteration in the imperial weights and measures required to be used by the Pharmacopoeia of 1864. For all pharmaceutical purposes, however, the use of the metric system alone is employed in all paragraphs relating to analysis, whether gravimetric or volumetric. For measures of capacity the Pharmacopoeia continues to use imperial measuring vessels graduated at the legal temperature of 62° F. The official names of the metric capacity units are defined at 4° C, as generally on the Continent. The new Pharmacopoeia also follows foreign practice, and employs metric measures of capacity and volumetric vessels graduated at 15·5 C, or 60° F. Specific gravity bottles are also adjusted at 60° F, the figures indicating specific gravities being quotients obtained by dividing in each instance the weight of the solid or liquid by the weight of an equal bulk of water, both taken at 60° F.

10. **Gauges.**—"Gauges," as understood at one time, included only those used in the measurement of barrels, casks, etc., and hence the term "gauger." For engineering and manufacturing purposes the more important linear gauges are, however, now used, adjusted to some fundamental unit of measure as the inch; although in certain trades, as for wires and flat metals, gauges continue to be used of arbitrary scales and of merely numerical sizes, having no reference to a legal unit of measure; and such are rarely accurate. Three standard gauges have been authorized for industrial use by Orders in Council: Whitworth gauges for cylinders (⅛ in. to 6 in.) and planes (0·01 in. to 0·1 in.) by Order dated August 1881; the Imperial Wire Gauge (S.W.G.) having numbered sizes from 7/0 (0·5 in.) to 50 (0·001 in.) (Order dated August 1883), and the Birmingham Gauge (B.G.) with sizes from 15/0 (1·000 in.) to 52 (0·00095 in.) (July 1914).

11. **Screws.**—The screw is an important productive measuring instrument, whether used as a micrometer-screw of less than an inch in length, or as a master-screw of 20 feet in length. The probable errors and eccentricities of small micrometer-screws have been carefully investigated to ±0·00001 inch; but the accuracy of leading screws used in workshops has not been sufficiently verified. For some engineering purposes it would appear to be desirable to produce master-screws to an accuracy of $\frac{1}{2000}$ of an inch to the foot of screw, so as to serve indirectly for the verification of "guiding screws" for general use in workshops. Attempts in this direction were originally made by Whitworth, Clement, Donkin, Rogers, Bond and others, but we still need a higher accuracy in screw-threads. The tolerances permissible in screw threads are discussed in Report No. 84 of the British Engineering Standards Association (B.E.S.A.). Screw threads used in the United States have been standardized by the National Screw Thread Commission. (See *Miscellaneous Publications of the Bureau of Standards No. 89.*)

Table of the Principal Weights and Measures now in use, and of their Equivalents in Imperial or in Metric Weights and Measures (excluding those already discussed)

Acre	United States	4,840 square yards.
	Great Britain	4,046·849 square metres.
Almude	Portugal	16·5 litres.
	Spain	4·625 litres = $\frac{1}{12}$ fanega (dry measure).
Ångström Unit (Spectroscopy)		10^{-10} metre = $\frac{1}{10{,}000}$ micron.
Anker	Latvia	38·256 litres, or 30 stoof.
Anoman (Ammomam, Amomam)	Ceylon	0·699 quarter (dry measure), 5·60 bushels.
Ara	Italy	1 metric are, 119·6 sq.yds.
Archin, or Arshin	Turkey	1 new archin (Law 1881) = 1 metre (39·37 inches) = 10 parmaks (decimetres) = 100 khats (centimetres), 1 mill = 1,000 archins (kilometre). Pharoagh = 10 mills. Another pharoagh = 2 hours' journey.
Archin	Bulgaria	0·758 metre (masons). 0·680 metre (tailors).
Archine, or Archinne	Russia Estonia	28 inches, or 0·7112 metre.
Ardeb	Egypt	5·447 bushels (Customs). 5 bushels (old measure).
Are		100 sq.metres = 119·6 sq.yds.
Area	Spain	1 metric are.
Arpent	France Canada	Legal arpent was equal to 100 sq. perches = 51·07 metric ares. In Quebec = 180 French feet.
Arroba	Portugal	14·68 to 15 kilogrammes.
	Spain	Wine = 3·55 gallons; oil = 2·77 gallons.
Artaba	Persia	1·809 bushel. Menor = 2·76 gallons (liquid).
Aune	Belgium	1 metre. Formerly 1·312 yard.
	France	1·885 metre (1812).
	Jersey	4 feet.
Barile	Rome	12·834 gallons.
Bat, or Tical	Siam	234 grains.
Batman	Persia	6½ lb. av.; varies locally.
	Turkestan	125 kg. (variable).
Behär	Arabia	439·45 lb. av., nearly.
Berri	Turkey	1·084 mile (old measure).
Boisseau	Belgium	15 litres.
Boutylka	Russia	1·353 pint (wine bottle).
Braça	Portugal	2·22 metres.
Braccio	Spain	0·670 metre (commercial).
	Rome	Braccio-d'ara = 29·528 inches.
Brasse	France	5·328 feet.
Braza	Argentina	5·682 feet.
Bu, or tsubo	Japan	$\frac{100}{30{\cdot}25}$ = 3·306 square metres (area). Also = $\frac{1}{100}$ shaku (length).
Bushel	United States Canada	2,150·42 cubic inches, about 0·96944 imperial bushel. 1 bushel = 8 gallons = 32 quarts = 64 pints.
Bunder	Netherlands	2·471 acres (old hectare).
Cable length		720 feet.

Cabot	Jersey	10 pots, or 4 gallons, 1 quart 3 gills imperial measure.
Candy	Bombay	560 lb. av.
	Madras	493·7 lb. av.
Cantar	Turkey	124·7 lb. av. (old weight).
Cantara	Spain	1 arroba.
Cantara piccolo	Italy	74·771 lb. av.
Capicha	Persia	0·58 gallon.
Carat	. . .	Metric = 200 mg.; for diamonds = $\frac{1}{150}$ oz. troy.
Catty	China	$1\frac{1}{3}$ lb. av. *See* Tael.
	N. Borneo	$1\frac{1}{3}$ lb. av.
	Siam	2·675 lb. av., or $\frac{1}{80}$ hap.
Cawnie	Madras	1·322 acre.
Cental	U. States, Canada	100 lb. av. (As in Great Britain.)
Centigramme		= $\frac{1}{100}$ grm. = 0·154 grain.
Centilitre		= $\frac{1}{100}$ litre = 0·07 gill.
Centimetre		= 0·394 inch = $\frac{1}{100}$ m.
Centimetre, cubic (c.c.)		= 0·061 cubic inch, or 1 c.c.
Centimetre, square		= 0·155 square inch.
Centner	Austria	50 kilogrammes = 110·231 lb. av.
	Denmark	50 kilogrammes = 110·231 lb. av.
	Switzerland	50 kilogrammes = 110·231 lb.
Chain	Canada	66 feet.
	Cyprus	0·33 pic.
Chang	China	10 ch'ih = 11 ft. 9 inches (Treaty).
	Siam	1,200 grammes.
Chapah	N. Borneo	$1\frac{4}{3}$ lb. av.
Charka	Russia	0·866 gill = 0·218 pint.
Chee. *See* Tahil.		
Chek	Hong Kong	$14\frac{5}{8}$ inches.
Chenica	Persia	0·289 gallon.
Chetverte	Russia	5·772 bushels = 8 tchetveriks, or 2·099 hectolitres.
Ch'ien	China	$58\frac{1}{3}$ grains (silver weight).
Ch'ih	China	Varies throughout China from 11 to 15·8 inches. For Customs purposes the Treaty ch'ih = 14·1 inches, and 5 ch'ih = 1 pu.
Ch'ih	Peking	= 12·3, = 12·5 } public works. = 12·4 statistics. = 12·6 architects. = 12·7 common. = 13·1 tribunal of mathematics.
	Shanghai	= 13·2 Board of Revenue. = 14·1 Customs.
Chilogrammo	Italy	1 kilogramme.
Chin or Catty	China	$1\frac{1}{3}$ lb. av. (Treaty).
Ching	China	121 sq.feet (Treaty).
Ch'ing	China	72,600 sq.feet (Treaty).
Chittack	Bengal	5 tolas, or 900 grains.
Ch'ok	Corea	$7\frac{3}{4}$ in. (linear); $12\frac{1}{8}$ in. (building).
Chô	Japan	As unit length = 360 shaku. As unit area = 3,000 bu.
Chüo	China	1,815 sq.feet (Treaty).
Chupah	Singapore	1·66 lb. av. of water at 62° F., as a measure of capacity.
	Malacca	144 oz. av. of water.
Chupak	Straits Settlements	1 quart.
Collothun	Persia	1·809 gallon.
Coss	Bengal	1·136 metre.
Covado	Portugal	0·66 metre.
Covid, or Cubit	Madras	18 to 21 inches.
	Bombay	18 inches.
	Siam	18 inches.
Covido	Arabia	18 inches approximately.
Covido (Great)	. . .	27 inches.
Cuartillo	Spain	1·16 litre (dry); 0·504 litre (liquid).
Daktylon (Royal)	Greece	1 centimetre.
Daribah	Egypt	43·58 bushels (Customs).
Decagramme		= 10 grms. = 5·64 drams av.
Decalitre		= 10 litres = 2·2 gallons.
Decametre		= 10·936 yards.
Déçiatina	Russia	= 2,400 square sagènes = 2·7 acres.
Decigramme		= $\frac{1}{10}$ grm. = 1·54 grain.
Decilitre		= $\frac{1}{10}$ litre = 0·176 pint.
Decimetre		= 3·937 inches = 0·1 metre.
Decimetre, cubic		= 1,000 c.c. = 61·024 cu.in.
Decimetre, square		= 100 sq. cm. = 15·5 sq.in.
Denaro	Italy	1 gramme.
Denaro	Rome	18·17 grains (old weight).
Deunam	Turkey	1 metric are.

Diraa	Egypt	0·58 metre = 1 pic.
Diraa, or Drâa, or Pic	Egypt	27 inches usually. 21·3 inches Nile measure.
	Turkey	27 inches (old measure of pike).
Dirhem	Egypt	1·761 dram av. (Customs). 3·0884 grammes (Cairo).
Dito	Italy	1 centimetre.
Djerib	Turkey	1 hectare.
Dolia, or Dola	Russia	0·686 grain. 96 doli = 1 zolotnick.
Drachma	Netherlands	3·906 grammes.
	Turkey	154·324 grains.
Drachmé (Royal)	Greece	1 gramme (gold weight).
	Constantinople	= 57·871 grains. *See* Ock.
Dram. See *Oke*.		
Dram	Persia	1 gramme.
Ducat	Vienna	53·873 grains.
Duim	Netherlands	1 centimetre.
Eimer	Austria	12·448 gallons.
El	Netherlands	1 metre. (Old el = 27·08 inches.)
Ell	Jersey	4 feet.
Ella	N. Borneo	1 yard.
Elle	Latvia	0·537 metre.
	Livonia	0·6096 metre.
	Switzerland	0·6561 yard.
Estadio	Portugal (old)	258 metres.
Faden	Latvia	4·077 stere.
Faltche	Moldavia	1 hectare, 43 ares, 22 centiares.
Fanega	Argentina	3·773 bushels.
	Portugal	55·364 litres.
	Spain	1·526 bushel.
	Peru	$1\frac{1}{2}$ bushel.
		1·615 acre, but varies locally.
Fass	Germany	1 hectolitre.
Feddan	Egypt	1·038 acre (Masri). Also 1·127 acre locally. 1·266 acre (old).
Fen	China	5·83 grains (silver weight).
Firkin	Great Britain	9 gallons (dry measure).
Fjerdingkar	Denmark	0·9564 bushel.
Fod	Denmark	1·0297 foot.
	Norway	0·3137 metre.
Foglietta	Rome	0·8 pint.
Foot	U. States	12 inches.
	Canada	French foot = 12·8 inches.
	Amsterdam, South Africa	11·147 in. } old measure.
	Old Rhenish	12·356 in. } old measure.
Fot	Sweden	11·689 in. 10 fot = 1 stöng. 1 ref = 10 stänger. 1 mil = 360 ref.
Founte, or Funt or Livre	Russia	0·90282 lb. av.
Foute, or Pied	Russia	1 English foot.
Frasco	Argentina	$2\frac{3}{8}$ litres.
Funt	Poland	405·504 grammes.
Fusz	Vienna	12 zolls = 1·037 foot.
	Switzerland	$3\frac{1}{3}$ fusz = 1 metre. See *Stab*.
Gallon	United States, Canada	231 cubic inches = 8·3389 lb. av. of water at 39·8° Fahr. At 62° Fahr. = 0·8325 imp. gallon.
Gantang	Straits Settlements	32 gallons.
	N. Borneo	144 oz. av. weight of water as measure of capacity.
Garnetz	Russia	0·3607 peck.
Gin. See *Kati*.		
Gisla	Zanzibar	Measure of 360 lb. av. of rice.
Go	Japan	180·39 cubic centimetres.
Grain	Russia	0·960 grain (apothecaries).
Gramme (gr.)	. . .	= 15·4323564 grains av. troy. = 0·2572 drachm, or 0·7716 scruple. = 0·03215 oz. troy.
Grammé (Royal)	Greece	1 millimetre.
Gramo	Spain	1 gramme.
Grano	Rome	0·757 grain.
Grao	Portugal	0·768 grain; also measure 0·18 in.
Grein	Netherlands	= 0·065 gramme.
Guz, or Gudge	India: Bengal	36 inches.
	„ Bombay	27 inches.
	„ Madras	33 inches, Government Survey.

Guz, or Gudge	Persia	The [illegible] varies from [illegible] to [illegible] inches. A guz of 40·65 inches [illegible] Arish [illegible] is common. Government standard guz = [illegible] inches. There is a [illegible] retail trade of 25 inches.
	Arabia	25 inches to 27 inches (Bassorah).
Hath, or Moolum, or Cubit	Bengal	18 inches.
	Bombay	18 inches, or cubit.
Hectare		= 100 ares, or 2·471 acres.
Hectogramme		100 grm. = 3·53 oz. av.
Hectolitre		100 litres = 2·75 bushels.
Hectometre		= 109·36 yards.
Hiyaka-me	Japan	5,787·205 grains.
Hiyak-kin	Japan	132½ lb. av.
Hogshead	Great Britain	63 gallons (dry measure).
Hoon. See *Tahil.*		
Hu	China	12½ gallons, nearly.
Hulmit	Latvia	11·48 litres.
Immi	Switzerland	1·5 litre.
Joch	Austria-Hungary	1·422 acre.
Kaima	Sweden	0·576 gallon.
Kan	Netherlands	1 litre.
	Hong Kong	1⅓ lb. av.
Kanne or Kanna	Germany	1 litre, or formerly 1·762 pint.
	Sweden	0·576 pint.
Kantar, or Cantaro	Egypt	99·0492 lb. av. = 100 rotls (Customs). 45 kilogrammes of cotton. 44·5 kilogrammes other produce.
Karwar	Persia	100 batman.
Kassabah	Egypt	3·8824 yards (Customs).
Kati, Catty or Gin	China, Straits Settlements	1⅓ lb. av.
Keddah	Egypt	2·0625 litres.
Keila, or Pishi	Zanzibar	Measure of 6 lb. av. of rice.
Ken	Japan	5·965 ft., 1·81 metre.
Kerât	Turkey	1⅛ inch measure (old).
		3·09 grains weight (old).
Kette, or Chain	Germany	14·994 ellen, or 10·936 yards.
Keu	Siam	40 inches.
Khat (New)	Turkey	1 centimetre.
Kile	Cyprus	8 gallons.
Killow	Turkey	0·97 bushel.
Kilogramme		= 1,000 grm. = 2·2046223 lb. av.
Kilometre		= 0·6214 mile.
Kin	Japan, China	0·601 kilogramme = 1·325 lb.
Klafter	Austria	= 2·0740 yards.
	Switzerland	1·9685 yard.
Knot	Great Britain	1 nautical mile = 6,080 feet.
Köddi	Arabia	1·67 gallon.
Koilon (Royal)	Greece	1 hectolitre. Old koilon = 33·16 litra.
Koku	Japan	= 39·7033 gal. = 4·9629 bushels.
Kon	Corea	1⅓ lb. av.
Korn-tonde	Norway	138·97 litres.
	Sweden	3·821 bushels.
Korn-top Maal	Norway	160 litres.
Korrel	Netherlands	1 decigramme.
Kotyle (Royal)	Greece	1 decilitre.
Kouza	Cyprus	9 quarts.
Koyan	Straits Setts.	5,333⅓ lb. av.
Krina	Bulgaria	12·8 litres.
Kung	China	78·96 inches (Treaty).
Kup	Siam	10 inches.
Kwan or Kuwan	Japan	8·281 lb. = $\frac{15}{4}$ kg.
Kwarta	Poland	1 litre.
Kyat	Burma	100 kyats = 3·652 lb. av.
Lak't	Bulgaria	0·650 metre.
Last	Netherlands	30 hectolitres.
Latro	Czechoslovakia	1·917 metres.
Lëang	China	583⅓ grains (silver weight).
Lèkhâ	Bulgaria	229·83 sq.metres.
Li	China	About ⅓ mile = 360 pu. Varies with length of ch'ih.
		A small weight 0·583 grain.
Liang	China	1⅓ oz. 16 liang = 1 chin = 1⅓ lb. avoirdupois.
Libbra	Italy	0·7477 lb. av.
Libra	Argentina	1·0127 lb. av.
Libra (Castilian)	Spain, Mexico	[illegible]
Libra, or Arratel	Portugal	1·012 lb. av.
Light Year (astronomy)		$9{\cdot}4627 \times 10^{12}$ kilometres.
Line or Ligne	Paris	$\frac{1}{12}$ point, or 0·089 inch.
Linia	Russia	0·1 inch. 1 archine = 280 liniias.
Litra (Royal)	Greece	1 litre = 100 mystra.
Litre	Cyprus	2⅘ quarts.
Litre metric		= 1·7598 pint.
Litro	Spain, Italy	1 litre.
Livre (lb.)	Russia	0·90282 lb. av. Apoth. livre = 11·5204 oz. troy.
Livre-poids	Belgium	Kilogramme.
	France	0·4895 kilogramme.
Loket	Czechoslovakia	0·593 metre (Prague); 0·594 metre (Moravia); 0·579 metre (Silesia).
Lot	Germany	New Lot = 1 decagramme. Old lot, nearly ½ oz. av.
	Switzerland	15·625 grammes.
	Vienna	270·1 grains. Postal Lot 257·2 grains.
Maass	Austria	1·245 quart.
	Switzerland	2·64 gallons.
Maatze	Netherlands	1 decilitre.
Mace	China	58⅓ grains.
	N. Borneo	93⅓ lb. av.
Mahud	Arabia	2·04 lb. av.
Maik	Burmah	3 maik = cubit = 19½ inches.
Marc, or Mark	France	0·2448 kilogramme (old weight).
	Sweden	0·4645 lb. av.
	Vienna	4,331·37 grains = 24 karato.
Marco	Portugal	= 8 oncas = 229·5 grammes.
	Spain	3,550·54 grains.
Maund	India	82·286 lb. av., Government. 72⅔ lb. (old bazaar). 74·67 lb. av., factory. 28 lb. nearly, Bombay. 25 lb. nearly, Madras. 37 to 44 lb., Juggerat. Local maunds vary on either side of 80 lb.
Megametre (astronomy)		1,000,000 metres.
Metre (m.)	United States	39·37 inches.
	Great Britain	39·370113 inches = 1 m.
Metre, cubic		= 1,000 c.d. = 35·315 cubic feet.
Metre, square		= 100 square decimetres = 10·764 square feet.
Metro	Spain, Italy	1 metre.
Metz	Austria	1·691 bushel.
Micron (μ)	Austria	= $\frac{1}{1000}$ millimetre.
Micron (1μ)	Czechoslovakia	10^{-6} metre.
Miglio	Rome	0·925 mile.
Mijle	Netherlands	1 kilometre.
Mil, or Mill	Turkey	1,000 archins (new mil).
	Denmark	4·680 miles.
	Great Britain	10^{-3} inch.
Mile	Great Britain	Statute mile = 5,280 feet.
	United States	Nautical " = 6,080 "
Mile (postal)	Austria	4·714 miles.
Milha	Portugal	1·296 mile.
Mille	France	1·949 kilometre.
Milligramme	France	= $\frac{1}{1000}$ gramme = 0·015 grain.
Millilitre	France	= $\frac{1}{1000}$ litre.
Millimetre	France	= 0·03937 inch = $\frac{1}{1000}$ m.
Miscal	Persia	71 grains.
Mkono	East Africa	45·72 centimetres.
Mna	Greece	1½ kilogramme = 1·172 oka.
Momme	Japan	$\frac{1}{1000}$ kwan.
Morgen	Denmark, Norway, Prussia	0·631 acre.
	Netherlands (Old)	8,124·4346 square metres.
	South Africa	8,550 square metres.
Mou	China	Commonly 806·65 sq.yd. Varies locally. Shanghai = 6,600 sq.ft. (Municipal Council). By Customs Treaty = 920·417 sq.yds., based on ch'ih of 14·1 inches.
Mud	Netherlands	1 hectolitre.
Myriagramme		= 10 kilogrammes = 22·046 lb. av
Ngoma	East Africa	7½ keilas.

Obolos	Greece	1 decigramme.
Ock	Turkey	Legal ock (1881) = 100 drachmas. New batman = 10 ocks, and kantar = 10 batmans ock = 1 kilogramme.
Octavillo	Spain	0·29 litre.
Oitavo	Portugal	1·730 litre.
Oke	Bulgaria	1·28 litre (for liquids). 1·282 kilogramme (old).
	Cyprus	2⅘ lb. av. = 400 drams (Cyprus).
	Egypt	2·751 lb. av. (Customs). 2·805 lb. (Alexandria).
	Greece	2·80 lb. = 1·282 kilogramme. 1·33 litre.
	Turkey	1·1518 pint. 2·834 lb. av. (old weight).
Onça	Portugal	28·688 grammes.
Once	France	30·59 grammes (old).
Oncia	Rome	436·165 grains.
Onze	Netherlands	1 hectogramme. 10 onzen = pond.
Ounce	U. States	Av. ounce = 437·5 grains.
Packen	Russia	1,083·382 lb. av.
Palamé (Royal)	Greece	1 decimetre.
Palm	Holland	1 decimetre.
Palmo	Portugal	0·22 metre.
	Spain	8·346 inches.
Para	N. Borneo	90 lb. av.
Parah	Ceylon	5·59 pints.
Parasang. See *Persakh*.		
Parmak. See *Archin*.		
Parsec (astronomy)		$3{\cdot}084 \times 10^{13}$ km.
Passeree	Bengal	5 seers.
Pé	Portugal	⅓ metre (old).
Pecheus (Royal)	Greece	1 metre = 1·543 old pecheuse.
Pecul	China	133⅓ lb. av.
Perche	France, Canada	22 square pieds de roi. In Quebec 18 French feet.
Persakh, or Parasang	Persia	Probably 3·88 miles = 6,000 guz.
Pfund	Estonia	430 grammes.
	Germany	= 16 unzen = 32 Lot, 1·01 to 1·23 lb. av. old weight. Zoll pfund (1872) = 500 grammes.
	Latvia	419 grammes.
	Prussia	Old zoll lb. = 1·1023 lb. av.
	Switzerland	500 grammes = 16 unze. Apoth. pf. = 375 grammes.
	Vienna	Pfund = 560·06 grammes. Zoll. pfund (1871) = 500 grammes.
Pharoagh. See *Archin*.		
Pic	Cyprus	2 feet.
Picul	Japan, Straits Settlements, Hong Kong	133⅓ lb. av.
	North Borneo	A measure of 180 lb. weight of water.
Picki	Greece	0·648 metre.
	China	25 gallons (dry measure).
Pie	Rome	11·73 inches.
Pie de Burgos	Spain	11·13 inches.
Pied	Belgium	11·81 inches = 10 pounces.
	Canada	12·79 inches.
Pied de Roi	Paris	0·3248 metre.
Pike	Turkey	See *Diraa*
Pint	United States	half a quart = 0·8325 imperial pint.
Pinte	France	0·931 litre.
Pipa	Portugal	534 litres (Oporto). 420 litres (Lisbon). 500 litres (officially).
Pipe	Gibraltar	105 to 126 gallons.
Pishi. See *Keila*.		
Poide de Marc	France	0·2448 kilo = 8 onces.
Polegada	Portugal	27·77 millimetres.
Pond	Netherlands	1 kilogramme. Apothecaries, pond = 375 grammes.
Pot	Denmark	1·7 pint = 4 paegle.
	Switzerland	2·64 pints or 1·5 litre.
	Belgium	1½ litre (dry). ½ litre (liquid).
	Norway	0·965 litre.
Pouce	France	1·066 inch (old measure).
	Russia	1 inch.
Poud, or Pood	Russia	0·016122 ton = 36 lb.
Pound	United States	Standard troy lb. = 5,760 grains. Avoir. lb. = 7,000 grains.
	Russia	0·90282 lb. av. (0·4095 kilogramme).
	Jersey	7,561 grains = 16 oz. Jersey = 1 livre.
Pu	China	70·5 inches = 5 ch'ih.
Puddee	Madras	2·89 pints. 100 cubic inches = Government puddee.
Pulgada	Spain	0·927 inch.
Pund	Denmark	1·1023 lb. av., or 500 grammes.
	Norway	0·4981 kilogramme.
	Sweden	6,560 grains. Varies locally. 5,500·5 grains (apoth.).
Quart	United States	See *Bushel*.
Quarto	Rome	2·024 bushels.
	Portugal	3·46 litres.
Quintal	Spain	100 libras (Castilian) = 101·4 lb.
	Portugal	58·752 kilogrammes, or 129½ lb. av.
	Argentina	100 libras, or 101·27 lb. av.
Quintal (metric)	France	= 100 kilogrammes = 1·968 cwt.
Quintale	Italy	1 metric quintal.
Ralte	Persia	1 litre.
Ratel	Persia	1·014 lb. av.
Rattel, or Rottle	Arabia	1·02 lb. av., nearly (dry measure). 17·219 lb. av. weight.
Ri	Japan	2·440 miles (itinerary). 2·118 miles (natural).
Rode	Denmark	3·762 metres.
Roede	Netherlands	1 dekametre.
Rotl, or Rottolo	Egypt	0·9905 lb. av. (Customs). 0·9805 lb. av. (Govt.).
	Cairo	2·206 lb. great rottolo. 0·715 lb. less rottolo.
	Alexandria	2·124 lb. great rottolo. Rottolo mina = ⅝ oka.
Rottol	Turkey	2·513 pints (old measure).
Rubbio	Spain	1·012 quarter (dry measure).
Sagène	Russia	7 feet.
Scheffel	Germany	50 litres, formerly 14·56 metzen (Prussia).
Schepel	Netherlands	1 decalitre.
Schoppen	Germany	½ litre, formerly 0·11 gallon.
	Switzerland	0·375 litre.
Se	Japan	118·615 square yards (·9918 are).
Seer	India	Government seer = 2 2/35 lb. av. Bengal, 80 tolas weight of rice (heaped measure), about 60 cubic inches (struck measure). Southern India = weight of 24 current rupees. Madras, 25 lb. nearly. Juggerat, weight of 40 local rupees. Bombay, old seer, about 28 lb.
	Ceylon	Measure of 1·86 pint.
	Persia	16 miscals, or 1,136 grains weight (Sihr).
	Note.—In India the seer, like the maund, varies considerably; usually 40 seers go to a maund.	
Seidel	Austria	0·6224 pint.
Sen	Siam	44·4 miles, nearly.
Ser	India	1 litre (Indian Law, 1871).
Shaku	Japan	10/33 m., also 9·18273 square decimetres; also 18·039 cubic centimetres (1/100 shô).
Sheng	China	1·813 pint.
Shih	China	160 lb.
Shô	Japan	1·804 litre.
Skaal-pund	Sweden	435·076 grammes, or 0·959 lb. av.
	Norway	0·4981 kilogramme, or officially ½ kilogramme.
Skeppe	Denmark	17·39 litres.
Skjeppe	Norway	17·37 litres.
Stab	Germany	1 metre, or 3⅓ old fuss, but varied.
Stadron (Royal)	Greece	1 kilometre.
Stere (metric)		1 cubic metre.
Stero	Italy	1 metric stere.
Stopa	Poland	0·288 metre.
Streepe	Holland	1 millimetre.
Stremma	Greece	1 metric are. 238·1 square pecheus (Constantinople).
Strich	Germany	1 millimetre.

Striche	Switzerland	$3\frac{1}{3}$ strich = 1 millimetre.
Stunde	Germany	Old itinerary measure, 2·3 to 3·4 miles.
Stunde .	Switzerland	4·8 kilometres. Stunder = 5 stunden, or 24 kilometres.
Sultchek	Turkey	Cubic measure (1881) whose sides equal a parmak (decimetre).
Sung .	Corea .	4 lb. av., nearly.
Tael .	Siam	$930\frac{1}{4}$ grains.
	Hong Kong	$1\frac{1}{3}$ oz. av.
	China	Silver weight, $1\frac{1}{3}$ oz. av.
	Japan	10 momme.
	(No current *coin* of the tael.)	
Tahil	Straits Settlements	$1\frac{1}{3}$ oz. av. = 10 chee = 100 hoon.
Tam . .	Hong Kong	$133\frac{1}{3}$ lb. av.
Tan .	China	= 25 gallons. Also $133\frac{1}{2}$ lb. weight.
Tang	Burma	2 miles, nearly.
Tang-sun .	China	About $3\frac{1}{2}$ miles = 10 li.
Tank .	Bombay . .	$17\frac{7}{12}$ grains, or 72 tanks = 30 pice.
Teng . .	Burma . .	Burmese measures of capacity depend on the teng or basket. Officially a basket is 2,218·2 cubic inches, but the teng varies locally:— Akyab = 23 lb. of rice. Bassein = 51 lb. of rice. Moulmein = 48 lb. of rice. Rangoon = 48 to 50 lb. of rice.
Thanan . .	Siam . . .	1 litre.
Thangsat .	Siam . .	4·688 gallons.
To . .	Japan	18·0391 litres = 3·9703 gal. = 1·98 pecks.
Toise . . .	France	2·1315 yards.
Tola . . .	India . .	180 grains. Legal weight of rupee.
Tomand . .	Arabia .	187·17 lb. av. of rice.
Ton . . .	United States .	2,240 lb. av., also a net ton of 2,000 lb.
Tönde . . .	Denmark . .	131·392 litres (liquid measure). 139·121 litres (dry measure).
Tonne, or Millier.	France . }	1,000 kilogrammes.
	Germany . }	
Tonne (metric)		1,000 kilogrammes = 0·9842 ton.
Tonnelada .	Portugal .	793·15 kilogrammes.
Tonos . . .	Greece . .	29·526 cwt.
Tou . . .	China . .	18 pints approximately.
Tovar . . .	Bulgaria .	128·2 kilogrammes.
T'sun . . .	China . .	1·41 inch (Treaty measure).
Tu	China . .	100·142 miles = 25 li, based on the ch'ih of 14·1 inches.
Vara . .	Peru . .	33 inches.
	Spain . .	2·782 feet.
	Argentina .	2·841 feet.
	Portugal .	1·11 metre.
Vat . . .	Holland . .	1 hectolitre. 768 mingelen. 1 mingelen = 1·20 to 1·237 litre.
Vedro . .	Russia . .	2·7056 gallons = 10 schtoffs, or 12·3 litres.
	Bulgaria . .	12·8 litres.
Verchok .	Russia . .	1·75 inch.
Versta, or Verst .	Russia . .	0·66288 mile.
Vierkanteroede .	Holland . .	1 metric are.
Viertel . . .	Denmark .	1·7 gallon.
	Switzerland .	15 litres.
Viss . . .	Rangoon . .	$3\frac{91}{140}$ lb. av.
Wa. . . .	Siam . . .	2 metres.
Wigtje . . .	Netherlands .	1 gramme.
Wisse . . .	Netherlands .	1 metric stere.
Yard . . .	United States	36 inches.
	Mexico . .	838 centimetres.
Zac. . . .	Netherlands .	1 hectolitre.
Zar (metric) . .	Persia . .	1 metre.
Zer (Persia). See *Guz*.		
Zoll . . .	Switzerland .	$3\frac{1}{3}$ zoll = 1 decimetre. Old zoll nearly one inch. (See also *Pfund*.)
Zolotnik . .	Russia . .	65·8306 grains, or 96 doli.

Bibliography.—In addition to the references in the text see *British Weights and Measures*, by Col. Sir C. M. Watson (1910) for the history thereof; and the *Travaux et Mémoires* of the C.I.P.M. for methods used for the comparison of standards. A long list of foreign weights and measures is given in vol. 1 of the International Critical Tables (1026) to which reference has already been made. The *Standards Yearbook* (U.S. Government Printing Office, Washington) contains a summary of the current work of the C.I.P.M. and of the various national and international standardizing associations. *History of Standard Weights and Measures of the United States* by Louis A. Fisher (Miscellaneous Publications of the Bureau of Standards no. 64).

(H. J. Ch.; O. Wo.)

MEASURES AND WEIGHTS, ANCIENT. The history of weights has been greatly extended, by (1) the discrimination of the ages of Egyptian weights by their forms; (2) the study of 3,400 weights and many capacity measures from Egypt; (3) the finding of the names and marks of four standards in Palestine, which confirms their independent position; (4) increased knowledge of prehistoric weights. Such material supersedes most of the fragmentary and vague statements of ancient authors, upon which we were formerly dependent.

The English standards of inches and grains are the most familiar, and are here placed on the left side of the column, while the equivalents in millimetres and grammes are inset on the right side. Only the values actually found are here described, without any theoretical amounts, or assumed connections. There is nothing easier than to frame systems of plausible relations between measures, but the exact amounts must be ascertained and the historic probability of descent, before such theories can be valued.

Lineal measures. *The units derived from 20·62 inches*

inches 20·62 — This standard of the cubit was used in Egypt from the time of the predynastic royal tombs onwards. The first accurate example yet published is in the size of the pyramid of Snefru (3rd dyn.), at 20·66, but still more exactly 20·62 in the pyramid of Khufu. The pure system of it was: — mm. 524

n,	100 = meh cubit,	100 = khet
·206	20·62	2062 inches

But it was mixed with other systems as:

zebo, digit	4 = shep, palm	7 = meh, cubit	100 = khet, reel	120 = ater or skhoinos
·737	2·947	20·62	2062	3·9 miles.

This was termed the "royal cubit" throughout history. The Babylonian 20·89 of Gudea may be another form, and probably the origin, of this. It appears in Asia Minor as 20·55 to 20·94; in tombs at Jerusalem as 20·57; in six English stone circles as 20·55. The eastern system was:

uban,	5 = qat,	6 = ammat,	6 = qanu,	60 = sos,	30 = parasang,	2 = kaspu
·695	3·475	20·85	125·1	7506	225,180	450,360

The same cubit of 20·68 appears in stone buildings of New Mexico.

12·45 — This foot is $\frac{3}{5}$ of the cubit of 20·75. It is found in Athens as 12·44, Aigina 12·40, Miletos 12·51, Olympia 12·62, Etruria 12·45, mediaeval England 12·47. The system was: — 316

foot,	10 = akaina,	10 = plethron,	6 = stadion
12·45	124·5	1245	7470

From the foot was formed a cubit of 18·7, — 474

foot,	$1\frac{1}{2}$ = cubit,	4 = orguia,	100 = stadion
12·45	18·7	74·7	7470

13·8 — Another foot was formed of $\frac{2}{3}$ of the cubit, adopted by Philetairos of Pergamon as a standard. — 350

17·72 — This was the short cubit of Egypt, actually found as a measuring rod and having 6 palms it was directly connected as $\frac{6}{7}$ of the 20·67 cubit. As 17·6 it is recognized as the early Jewish cubit. — 450

The digit and derived measures.

inches ·729 — This digit was $\frac{1}{40}$ of the diagonal of the 20·62 cubit. The diagonal of the cubit, 40 digits, is found as a wand of the middle prehistoric age, 29·1 long. Another multiple was the half of this, 20 digits, called the remen, used as a basis of land measure. By having two systems, one the diagonal of the other, it was possible to denote one square half the area of another. — mm. 18·51

digit,	100 = orguia,	10 = amma,	10 = stadion: itinerary
·729	72·9	729	7290

inches | mm.

18·23 25 digits = Greek cubit of 18·23 **463**

12·15 ⅗ of 18·23 is the Greek foot of 12·15, from which was a decimal system. **309**

foot,	10=akaina,	10=plethron: agrarian
12·15	121·5	1215

This measure is rare in comparison with the 12·45 foot. It has been supposed to have been used for the Parthenon, but the 11·69 foot agrees more closely with that. The ⅗ of 25 digits, being a fractional amount, was inconvenient, and the foot of 12·15 was divided binarily into 16 digits, of 96 to the orguia, or ·759 inch. Such seems to have been the original connection of the different Greek systems, but much more dated material is needed.

11·613 From the digit of ·729, on which the Greek measures were based, as for the Parthenon **294·9**
11·69, the Italic foot of 16 digits was formed of 11·66, or as it was later at Rome 11·613; the series was

digitus,	4=palmus,	4=pes,	5=passus,	125=stadium,	8=milliare
·726	2·90	11·61	58·06	7258	58,060

This was widely spread by Roman influence, varying up to 11·8. It has an earlier history, being used for the Parthenon and perhaps the Theseion as 11·69, and as an Etruscan measure (**11·59**), also in prehistoric times at Stonehenge (**11·68**), and probably in other stone circles and hill figures (**11·60**). Such are the linked systems of great extent, from which have been derived many units.

13·3 This widespread measure is first found in Egypt, as wooden cubit rods of 26·5 to 26·74, **338**
of the 12th dynasty: later, a very accurate standard slab of this unit, divided in 7 palms, reaches 26·80. In Asia Minor it is found as 13·35 in buildings, in Greece 13·36, at Lachish 13·18 (900 B.C.), in Syria (A.D. 620) as 13·22, carried on as the Stambuli cubit of 26·6. Hultsch takes it as 13·1, and connects it with the Drusian foot of 2 digits longer than the Roman foot, or 13·10. This was the Belgic foot which Drusus had to adopt as a northern standard for the border settlements of the Agri Decumates. Hence it connects with the base of English land measure,

foot,	6=fathom,	10=chain,	10=furlong,	10=old mile
13·2	79·2	792	7920	79,200

It was the commonest building foot in mediaeval England (**13·2**), and its age is seen by its use as the measure for Silbury hill (13·0). It was also the basis for French architecture, the *canne* of 78·24, or six feet of 13·04. Unfortunately this old equivalent for the metre has now disappeared.

19·2 This unit is found in Persepolis (**19·2**), and modern Persia (**2×19·3**), also the cubit of **488**
Gudea and of the tower of Babylon (**19·5**); in the west in Asia Minor (**19·3**) and as the Pythic foot (**9·75, ½19·5**). Two-thirds of this, a foot of 12·83, seems to be a unit of buildings at Knossos.

20·0 The great U of 39·96 (Oppert) is possibly a variant of the preceding, found in some Assyrian buildings as 19·97. **507**

21·6 By the recorded circuit of Khorsabad the U is 10·806, hence the series of multiples on the tablets is: **549**

susi,	20=palm,	3=U,	6=qanu,	2=sa,	60=us,	30=kasbu
·18	3·6	10·8	64·8	129·6	7776	233,280

In Phrygia this was 21·8 at Ushak; in Italy it was 21·86 in Lucania, and half of 21·7 or 21·9 as the Oscan foot. It may occur in square prehistoric earthworks in England. In Egypt there are late cubits of 21·11, 21·16, 21·33 which may be the same. In Persia it was likewise a smaller form, as:

vitasti,	2=arasni,	360=asparsa,	30=parathanha,	2=gav.
10·7	21·4	7704	231,120	462,240

22·2 This important unit was used in Phoenicia, at Byblos 11·10, for the Erechtheion 11·09, and **564**
in Punic Colonies, Carthage, Sardinia, and the Hauran, 11·08–11·17. The double of 11·30 is the commonest unit of tombs at Jerusalem.

inches | mm.

25·1 There are very few evidences of this measure. Divisions on a wall at Abydos give 25·13. The contents of the brazen sea of Solomon, taking **638**
the bath as 2380 c.c., would imply a cubit of 23·0 if cylindrical, or 26·2 if hemispherical. This at least proves a cubit much longer than the Egyptian. Oppert concluded that Assyria had a cubit one-sixth longer than 21·6, *i.e.*, 25·2. Measures of buildings point to 25·28 in Palestine, and 25·34 in Persia, where the *guerze* is 25 inches.

There are not included here some suggestive but debatable evidences of various units, such as the course heights of the pyramid of Khufu (*Anc. Eg.* **1925,39**), and the subsidiary marks of units on the standard cubits.

It may be noted how usually a stadium or furlong measure has been established; there are seven named above, 7258, 7290, 7470, 7506, 7704, 7776 and 7920 inches. These may result from convenient lengths for the plough furrow. It is easy to find coincidences with so many values to choose from.

Areas are passed by, as they involve very uncertain factors of methods of cultivation, length of furrow, influence of measures of seed, and varying ability of ploughing due to soil.

Capacity Measures

The approximate values of Egyptian capacities are anciently stated by the odd quantities that certain vases held; but as these were probably measured to some unknown point below the brim, the result cannot be exactly defined. The standard vessels, here described, intended for gauging, give better determinations than have been known before.

cubic inches | c.c.

29·1 The amount of the Egyptian hen by five regular measures (of metal or stone) averages 29·2 ≑ ·5cu. in., from ten bronze vessels 29·0 ≑ ·3, from eight marked vases 29·2 ≑ ·6. So 29·1 **477**
may best be adopted. If it held 5 debens of water the deben weight would be 1,470 grains, which is nearly a middle value. The multiples are

ro,	8=hen,	4=hennu,	10=apt,	4=tama,	25=sa
3·64	29·1	116·4	1164	4656	116,400

20·8 **21·6** There is a double grouping of the Syrian kotyle, on 20·8 and on 21·6. This is supported by the literary difference between the old **341** **354**
Syrian 21 and Seleucidan 22 cu. in. (Hultsch). The cause for this change may have been that the old unit of 20·8 belonged to 25 beqa of water, and later it was raised so as to fall within the limit of 25 sela of water. The change would be caused by the sela superseding the beqa as a usual weight standard. In Egypt this was the commonest measure, of which there is a series of the 3rd dynasty, and a stone cylinder standard from the 4th, of 20·8. The series of early and late values is:

kotyle,	2=xestes,	18=sabitha or saton,	3=bath, artaba
20·8	41·6	7488	22,464
21·6	43·2	7776	23,328

There was also the metretes of 5 saton, 37,440 to 38,880.

33·2 The Syrian log was not unusual in Egypt. Nearly in the midst of the values for it, there **544**
is a bronze cylinder measure with names of Amenhetep III., of 33·26. If this log were to agree with 50 necef, the most usual Syrian weight, it would not be over 32·6 in early times, and would only reach 33·2 in the 18th dynasty. The Phoenician, Babylonian and Jewish systems vary as follows, the Egyptian amounts being placed to the latter series.

P. log, 31	4=kab, 123		6=saton 740		30=kor 22,200	
B. log, 33	4=kapitha, 132			18=epha, 2380	10=homer, 23,800	6=akhane 142,800
J. log, E. 33·2	4=kab, 132·8	3=hin, 398·4	2=seah 796·8	3=ephah, 2391	10=homer 23,910	

17·4 The Attic kotyle is found in the size of six similar bronze bowls of late form in Egypt, **285**
from ½ to 2 kotyles. The mean is 17·15. This amount is too small for an Attic weight, for if the khous were 8 minae of water, the largest bowl size would only agree with the lowest mina. But if the kotyle of water weighed half the mina of Chios

or Persia (khoirine system), this would place it at [illegible] to 17·5. In this dilemma the Persian kapetis has some influence. According to Herodotus ([illegible]) the Attic kotyle: kapetis : : 12 : [illegible] or 4 : 17. The kapetis is shown by two bowls mentioned below, to be 74·5 or 75·3, therefore the kotyle would be 17·5[illegible] or 17·72. If we take 17·4 that would leave the [illegible] of Herodotus the nearest whole number, and the small difference would thus be divided among the three factors. The series is for:

Liquids

kyathos,	[illegible]=oxybaphon,	4=kotyle,	12=khous,	12=metretes
2·9	4·35	17·4	208·8	25 050

Solids

[illegible]	[illegible]=kotyle,	4=khoinix,	8=hekteus,	6=medimnos
[illegible]	17·4	69·6	5568	33,408

cu. in. Two bowls of Persian age, from Egypt, are of c.c.
74·5 74·5 and 75·26, clearly the Persian kapetis. 1221
Their relation to the kotyle value is stated above. The multiples were:

kapetis,	48=artaba,	40=	akhane
74·5	3576		143,040
	maris,	72=	
	1987		

58·5 A system found at Gythion (Rev. Arch., 1872) is based upon 58·5 cu. in., and seems to belong to the Egyptian hen, double of which is 58·2. 958

kotyle,	4=hemihekton,	4=khous,	3=*n*
58·5	234	936	2808

1701 The most important Roman system is far from being established. The data are but few and discrepant. 27870

	amphora	sextarius	amphora	sextarius
If amphora=cube ft ...	1560 cu. in	32·7 cu. in.	25,709 c.c.	536 c.c.
Amphora 80 lib. water..	1575	32·8	25,807	538
	1605	33·4	26,300	548
By Farnese congius. ..	1654	34·4	27,102	563
St. Geneviève congius...	1700	35·4	27,856	580
Naples measures.......	1701	35 44	27,872	581
	1703	35 48	27,905	581
Pompeian standard ...	1732	36 1	28,377	591
Caervoran standard.....	1824	38·0	29,868	623

There does not seem any course better than to accept the two accurately made measures in the Naples Museum of 709·7 and 283·5 cu. in. as being 20 and 8 sextaria; this would give 1702 for the amphora, agreeing with the St. Geneviève congius. The Naples vessels are only measured by lineal gauging, but that cannot be far in error. The system was:

quartarius,	4=sextarius,	6=congius,	4=urna,	2=amphora
8·86	35·44	212·6	850 5	1701

Of the above sources the first two may be only approximate, and the Farnese congius is not above suspicion of a renaissance origin. The Pompeian measures seem too rough internally, and look as if they had held a beaten copper lining. The Caervoran measure is marked as 17½ sextarii, and this yields 38·0 cu. in.

Weights

The whole subject of weights as treated here is based on the Egyptian material, as that is by far the earliest and the best known historically, and in amount the largest published. The arrangement found in Egypt serves best to classify the standards of other countries. The broad view is that each people or tribe had a separate standard, and that these were brought into different countries by invasion or trade. Those standards which were most alike gradually approximated by errors of copying, and lost their individuality entirely before any of the literary records. Thus 17 standards in Egypt which had originally come from various foreign sources, became simplified to 8. They are here described in the order of their amount.

grains The peyem standard is marked P.Y.M. on grammes
116, three Palestine weights. The varieties named 7·52,
121, here were all known before the 6th dynasty; 7·86,
124 the two heavier were mixed at the 20th dynasty, the lighter one joined in the 26th. 8·06
There are twelve weights known marked with numerals, and the standard, called *shoti* in Egypt, is named on papyri as being 12 to the deben, or between 115 and 126 grains. The multiples were:

[illegible]	4=peyem,	10=noshem,	10=*r*,	4=*s*
[illegible]	120	1200	12,000	48,000 grains.

The noshem was 1225 grains according to a triply inscribed weight: the shekel or peyem being 122·5.

grains Two standards of the daric existed in the Old grammes
127·5, Kingdom, but they were blended in the 18th 8·26,
131·5 dynasty. The same separation is seen in the 8·55
weights from Ur, with a light group at 126·1 and a heavy group at 129·4. The earliest in Egypt is of S.D.40, or the beginning of the eastern immigration of Gerzean age; these centre on 125·5. The early weight of Dungi is of 125·9. A maneh of 50 shekels at 126·0 was used in Syria and Knidos. In Italy it was divided into unciae, and termed the litra. Italic bronze ingots of a talent are based on 126·0. On the heavier standard the Persian karasha was 10 shekels of 128·65. The coinage under the Persians (from which is taken the name Daric) was of 129·2, and some coins reach 131. The heavy standard at Knossos is 131·8, 132·9. This daric standard spread over Asia Minor and across the Euxine, also westward to Corinth, the Adriatic isles, South Italy, and even to Ireland (gold work 128·0). The series is:

um,	60=sikhir,	6=shekel,	60=maneh,	60=trade talanton
·36	21 5	129	7750	465,000

134·0, The Stater or Attic standard is the least prom- 8·68,
135·8 inent in Egypt; the forms are poor, and only 8·80
two examples bear numerals. The two standards were unified by the 18th dynasty, and the multiples are decimal. In Greece the system was:

khalkous,	8=obelos,	6=drachma,	100=mina,	60=talanton
1·4	11·17	67	6700	402,000

In Greek use there was a lighter form for coinage, 133, and a heavier form in trade, centring on 135. The names of obelos and drachma, or a dart and a handful (of darts), show how objects were used for weights in Greece. The names must have arisen in the use of iron or bronze weapons, and the silver coins were the exchange values. This standard passed into Italy, where it was halved for the Etruscan and Sicilian libra, and divided into 12 unciae. It was the talanton of Antioch and of the Ptolemies, and survived in Egypt as the rotl, divided duodecimally as in Italy, and so producing the dirhem which was the standard coin of Arabic Egypt.

144 The qedet was the national standard of Egypt, 9·33
brought in by the dynastic people. There are very few marked weights because it was so usual. Though there were not distinct groups in early times, yet there were local differences, as weights "of Heliopolis" are on 140 unit, while one of Amasis is 150. Alabaster cones are the earliest, belonging to the 1st dynasty; they are multiples of a third of the qedet; from Ur are six small weights that are multiples of a twelfth of the qedet so the division in thirds comes from Babylonia. There are many qedet weights from Gezer and Gerar, also from Knossos and Troy. A large knuckle-bone of bronze from Gela, inscribed "I am of the Gelonians" is 100 qedets. The unit, however, did not spread much in other countries, nor start other standards.

b,	4=*c*,	3=qedet,	2=khenp deben,	5=deben,	10=sep,	5=*d*
12	48	144	288	1440	14,400	72,000

The deben was binarily divided in Ethiopia for the gold trade, down to the *pek*, which was $\frac{1}{128}$. A set of measures for gold dust gives every stage of this division.

154·4, The necef is named on six Palestine weights; 10·0,
162 it may be the nusa weight mentioned in the 10·5
Harris papyrus. It was first identified by the weight of Syrian tribute to Tehutmes III. being in odd numbers of qedet, but soluble as multiples of this amount.* The two varieties of this unit did not blend till the 26th dynasty; the lighter was the Syrian standard of named weights, and was the

earlier one at Gezer. The system was decimal, multiplying up to 1,000, and halving down to $\frac{1}{8}$th. By the tribute lists it was North Syrian, and in later times is found at Berytus and Antioch, Cilicia (pre-Persian), Asia Minor, and a bronze lion from Abydos of 2,500 necef. On going west there is a $\frac{1}{4}$ necef at Knossos. It appears in the jewellery of the 17th dynasty at Thebes, a collar of gold weighing 10×158·5, and bangles 2×161·3, 162·9. This collar is of the same form as the three Swedish collars weighing 60×158·2, 70×155·9 and 80×158·7, all on the necef basis. Where all this necef jewellery was made is yet unknown, but it was entirely foreign both to Egypt and to Sweden. There are about 50 Irish gold objects on the heavy necef of 162 to 169. The Greek system was:

stater,	50=mina,	50=talanton / 60=Greek talanton
160	8000	400,000 / 480,000

grains 171, 185 — A mark ♀ is often used for this unit, but the name is not known in full. As many copies of cowry shells are on this (but on no other) — grammes 11·08, 12·00 — standard, it is called the khoirine, and perhaps the monogram is XO, as those letters were in use long before Greek writing. The bulk of the early examples is from 176 to 190; but there was a rarer form at 171–3, down to the 18th dynasty, and not blended with the majority till the 23rd. Three very fine numbered weights from Gerar closely agree in giving 179·3 to 179·8; the stone cowries are the same, but rather more divergent, 177·7 to 180·0. The multiples in Egypt are decimal up to 1,000, and fractions down to $\frac{1}{10}$. In later times it became the Persian silver standard, but all the theories of the derivation of an 86 grain weight, from the ratio of gold to silver, are blown away by the fact that this standard is thousands of years older. At Khorsabad silver plates are 40 khoirines in weight. As a monetary unit it is known at Arados, Cilicia, Lydia and Macedonia. It is known as the Chian standard, with a mina of 8,410 to 8,886. It was used on the Danube in Roman times, and recognized as a mina of 20 unciae. The classical system was:

obolos,	6=siglos,	100=mina,	60=talanton
14·3	86	8,600	516,000

196, 210 — The oldest standard known is the beqa, found in early Amratian graves in Egypt (7000–8000 B.C.), and named upon three weights in — 12·70, 13·61 — Palestine. This is often called the gold standard because many of these weights bear the hieroglyph for gold. The names of kings are more frequent on this than on other standards. The lighter and heavier forms were not unified until the 23rd dynasty, though both were used before for royal weights. The system was decimal up to 2,000 beqa, with fractions down to $\frac{1}{16}$. The earliest weights (Amratian) are short cylinders with domed ends; later (Gerzean) is a dome with convex base. From the marks, the variety of forms, and fine work, this is the most attractive series of weights. Abroad the standard is often found at Gerar and there are several weights from Knossos (**194–205**); in the west are six double axes from Elbe and Rhine, on a unit of 191, and 50 examples of Irish gold, on 200 to 202. The iron currency bars found in Celtic England are stated to be on multiples of 191, though they vary rather widely. Some of these western forms are due to the Greek adoption of the beqa as the standard of Aigina (**199**), which was widely spread by trade in Asia Minor and Ionia, as well as in Greece (the old mina of Athens), and passed on to Italy. There as the Etruscan pound (it originated the Roman libra), which at its lightest was 25×187, divided into 12 unciae.

5050, 421 — The heaviest value of the Roman libra is given by the early aurei as 5050, uncia 421. The influence of unification with other standards — 327·24, 27·27 — created many types of the libra, and it is instructive to see the groups at 393 (6 Attic coin drachma), 407 (6 Attic trade drachma), 412 (Roman trade), 417 (Roman solidi), 421 (Roman aurei), 427 (octodrachm Ptolemaic) and 435 (2 Phoenician staters). The Attic trade value was adopted for the average pigs of lead, which are 250 librae of 4,900 grs.; the Attic coinage value influenced the Celtic weights, Mayence 4767, Glamorgan 4770. The system was:

siliqua,	6=scripulum,	4=sextula,	6=uncia,	12=libra
2 9	17·5	70 1	421	5050

In later times the gold solidus, or sextula, was called the nomisma.

grains 220 — The Phoenician or Alexandrian unit is best termed the sela, which, though a later name, — grammes 14·26 — serves to distinguish it from other shekels. It was a diffuse unit from the beginning, varying in the Old Kingdom from 214·7 to 227·0; it gradually diminished to as low as 210. The multiples are decimal up to 4,000, and fractions to $\frac{1}{16}$. This is found as the unit of the Syro-Mesopotamian tribute under Tehutmes III., and later as one of the most usual coinage units, such as the Maccabaean shekel. It was carried by trade to Carthage and Spain, and formed the Italic mina. Gold bars from Abukir of Roman age are each 25 shekels of 211·7, 212·9, and 213·0. The series is:

drachma,	4=shekel,	25=mina,	120=talanton
55	220	5500	660,000

It extended widely into prehistoric Europe. At Knossos the great octopus weight shows a unit of 223·7, an ox-head from the Diktaian cave shows 227·2, a gold bar from Mykenai 233·1, another from Enkomi 222·6. The Vapheio cups are 20 sela of 213, and 216·5. Electrum jewellery from the temple of Ephesos is on a unit of 219·0. In Babylon the maneh of the age of Entemenna (2850 B.C.) is 50 of 210·1. The average of 19 ingots of bronze from Hagia Triada gives a talanton of 2,000 shekels of 226·0. Two double axes from the Rhine and four Ligurian ingots agree on 50 shekels of 225·4. The Irish gold has a large group agreeing with an average of 226·0. Thus there was a great spread of the unit, doubtless due to Phoenician trade.

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MEASURING TOOLS: *see* MACHINE-TOOLS; WOOD-WORKING MACHINERY and various articles under specific titles.

MEAT, in the narrowest sense, the flesh of veal, beef, pork, lamb and mutton producing animals. In a broader sense, meat includes the flesh of other animals such as fowls and birds. In a still broader sense, meat includes all the parts of the animal body used as food. This would classify lean flesh, fat flesh, skin, edible glands and organs all as meat. Such products contain water, protein, fat and mineral matter, together with small amounts of glycogen, meat extractives and other miscellaneous organic substances. The fat content will vary with the fatness of the animal. As the fat increases the other constituents decrease. The accompanying table gives the composition of typical flesh of various degrees of fatness.

Percentage Composition of Flesh (Beef)

	Water	Protein	Fat	Ash	Other constituents
Lean flesh . . .	73	20	5	1	1
Medium fat flesh . .	65	17	16	0·9	0·9
Very fat flesh . . .	35	9	55	0·5	0·5
Fat flesh (no lean) . .	9·7	2·5	87·5	0·1	0·1

Other edible parts differ more or less from the flesh in composition, although the same constituents are present and in somewhat similar proportions. The following table gives the composition of certain edible organs and parts. While the analyses given are for tissues of the beef animal, they represent rather accurately the

composition of the same parts of other animals

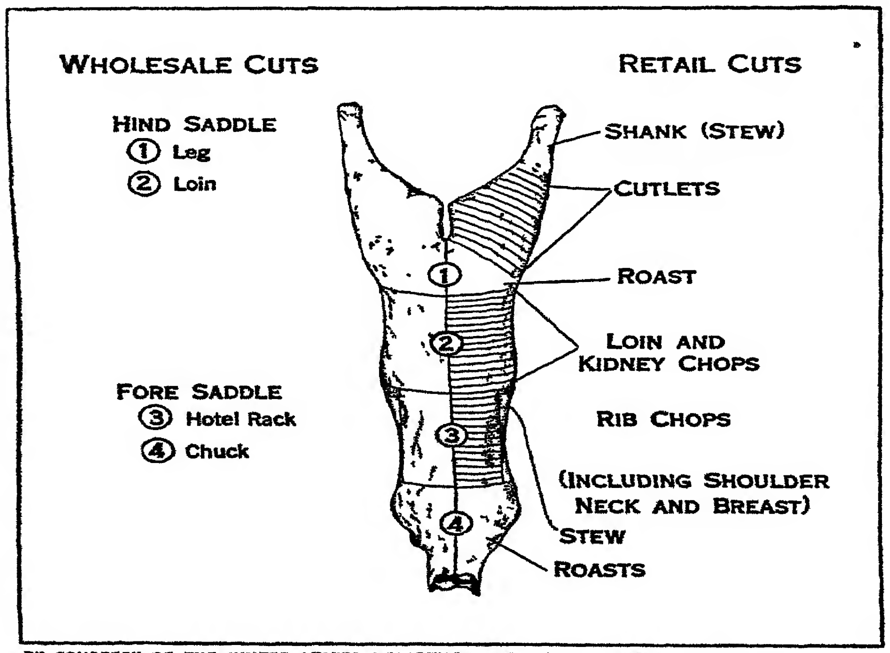
Percentage Composition of Edible Organs, Beef

	Water	Protein	Fat	Ash	Other constituents
Liver	[illegible]·5	[illegible]0·0	[illegible]·5	1·5	·5
Kidney	77	1[illegible]·5	[illegible]·5	1·1	[illegible]·0
Heart	77·5	1[illegible]·0	3·5	1·0	2·0
Tongue	67	16·0	13·5	0·9	2·5
Brains	71	10·8	13·5	1·7	3·0
Tripe	80	10·[illegible]	8·0	0·9	0·5

Digestibility.—The various meats and organs of animals are almost completely digested in the stomach and intestines. On the average, the fats are about 96% digestible, while the proteins may be even more completely digested. In addition to being almost entirely digestible, these animal foods are satisfying; that is, they remain in the stomach longer than starch and sugar foods and so they postpone the feeling of hunger. The fatter meats remain in the stomach longer than the leaner meats.

Food Value.—The food value of meat depends upon its content of protein, fat, mineral matter (or ash) and vitamins The protein is the most important constituent, both on account of the quantity present and also because of its quality Proteins have 18 or 20 constituent parts or kinds of "building stones," known as amino acids. These are of varying importance as food. Meat, especially the lean flesh, liver, kidney, heart and tongue, has a very complete assortment of these amino acids, and therefore stands very high in the scale of protein foods

Meat has some of all the necessary minerals. It is especially valuable for its phosphorus and iron. Recent investigations,

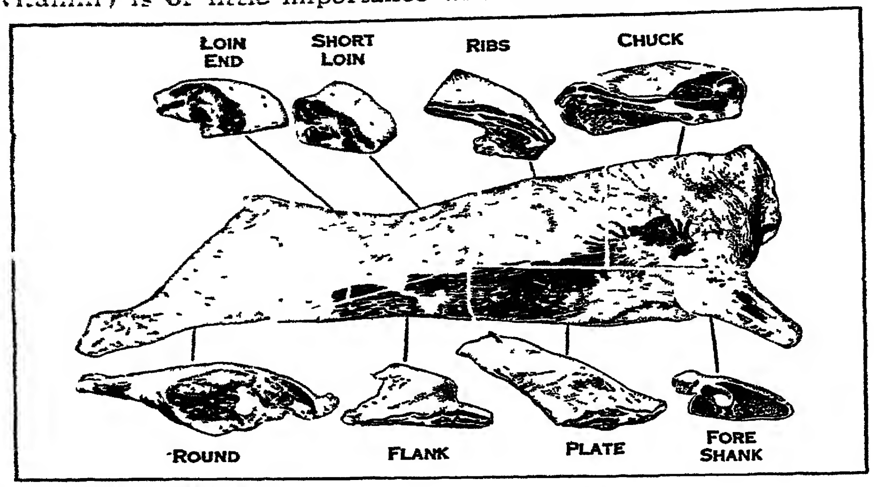


BY COURTESY OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

VEAL CHART SHOWING VARIOUS PARTS AND THEIR USES

especially with cases of pernicious anaemia, have shown that liver, kidney and lean meat are some of the most important iron-containing foods. The meats are low in calcium, another very important mineral element. This deficiency should be supplied by milk, cheese and the green, leafy vegetables. Meats, fish and cereals contain an excess of acid-forming over base-forming mineral elements. Vegetables and most fruits contain an excess of base-forming mineral elements. In order to balance the diet with respect to this factor, one should use foods from both groups in about equal proportions. Meat and potatoes, tongue and spinach, corned beef and cabbage, and spare ribs and sauerkraut are examples of combinations which meet this requirement.

Meats contain some of the important vitamins. Liver and kidney are especially rich in vitamins. Tongue and heart have a somewhat lower vitamin content. Lean flesh has ample quantities of vitamin B (the pellagra-preventing part of this complex) and E (the anti-sterility vitamin). The other vitamins are found in small quantity in flesh. The body fats may contain fair amounts of vitamin A The content of vitamin C (the scurvy-preventing vitamin) is of little importance when the meat is cooked. How-



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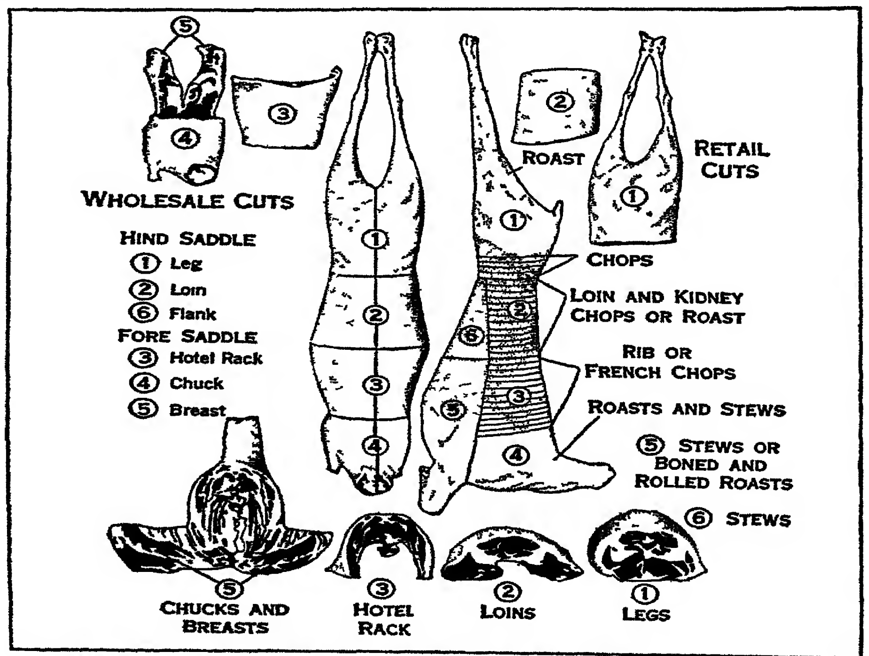
STANDARD BEEF CUTS, CHICAGO STYLE

ever, Eskimos and Arctic explorers have proven that fresh and under-cooked meat, when eaten in quantity, will cure or prevent scurvy.

Use in the Diet.—Meats are of importance in the diet not only on account of their food value but also because of their flavour and their stimulating effect upon the flow of digestive juices. Meat, especially the extractives, stimulates digestion by increasing the amount and activity of the gastric juice. It contrasts nicely in flavour with starchy and bland foods, and so helps in adding flavour to mixed dishes and to the diet as a whole. Since the proteins are very complete, they help to balance the less complete proteins found in cereals and vegetables.



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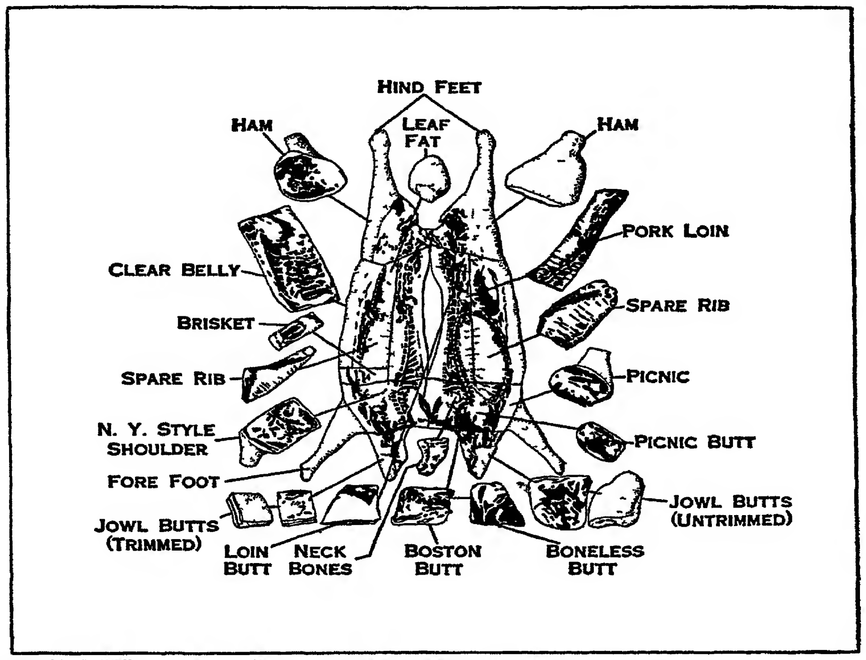
LAMB CHART SHOWING THE VARIOUS PARTS AND THEIR USES

Healthfulness.—Properly inspected, stored and prepared, meat is a healthy food, useful in the diet of most normal people. Being a good food of fairly high water content, fresh meat must be stored in refrigerated rooms or boxes until it is consumed. Otherwise it may spoil, just as milk, eggs, fish and other high

protein foods. Cured meats keep better than fresh meats. In common with most of these same foods, the animals and their meats should be given careful inspection by competent persons to ensure their wholesomeness. This is done under Government inspection in all establishments engaged in interstate trade.

The use of meats in a mixed diet can not be said to lead to any disease or disturbance of bodily metabolism. Certain sects



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FRESH PORK CHART, SHOWING VARIOUS CUTS

or groups of individuals believe such things, but science and the medical profession have shown there is no basis for such beliefs. On the contrary, the use of meats in a mixed diet is one of the factors that will lead to good health through proper nourishment.

(C. R. M.)

See also MEAT TRADE.

MEAT COOKERY. Butcher's meat may be roasted, baked, fried, grilled (broiled) or stewed. It may also be combined with pastry (*q.v.*) in meat pies, puddings, vol-au-vents, etc.; with cereals, vegetables (*see* CEREALS, VEGETABLE COOKERY and PULSE); and used in soups (*q.v.*).

Roasting and Baking.—To prepare meat for roasting or baking, wipe the meat, trim and truss it into shape if necessary to prevent spreading. Certain joints need boning and rolling, *e.g.*, a breast of mutton. In this case the bones are removed by slipping a sharp knife along the bone without cutting through the flesh. Boned meats may be spread with forcemeat. Bones should be used for stock. Basting is the most important of all requirements for roasting. Sufficient fat usually runs out of fat meats for the purpose but in meats which are deficient in fat, *e.g.*, veal, additional fat is necessary. Dredging the joint with flour helps to seal in the juices and also improves the colour of a roast joint and makes a better gravy. (*See* GRAVIES.) Small joints may be covered with brown paper to keep them from browning too much. Hams may be covered with a flour and water paste and baked in the oven. Pork which has a tough outer skin ought to be seared with a knife before roasting for the convenience of the carver. Stuffed meats are usually served with a thickened gravy; plain roasts with a clear gravy.

Boiling.—Joints for boiling should be securely tied with string. Fresh meats are placed in boiling salted water with pot herbs, *i.e.*, carrot, onion, ¼ turnip and a *bouquet garni* (parsley, bay leaf, thyme, etc.). Boil for ten minutes, skimming the water carefully. Where vegetables are being boiled with the meat for serving, these should not be added until the requisite time needed for cooking. It is usual to serve special vegetables or sauces with boiled meats to give extra flavour: *e.g.*, boiled mutton and caper sauce; bacon and pease pudding; boiled beef and carrots.

Ox tongues and hams require 24 hours' soaking before cooking to draw out the salt and pickle. Salted and pickled meats should be put into cold water and brought slowly to the boil. All boiled meats should be simmered after the first ten minutes.

Boiled meats which are to be used as cold dishes should be dressed, *e.g.*, ox tongues need skinning immediately after cooking, and when cool should be glazed. Hams also need skinning and should then be covered while warm with grated toast.

Calf's head should be cut down the middle, leaving the tongue whole. Remove the brains and soak the head in cold water for an hour. Soak the brains separately in salted water; then place them in cold water with a little lemon juice and boil for 15 minutes. When cooked mix with chopped sage and onion (one teaspoonful). Put the head into cold water, bring to a boil and rinse in cold water. Return to the fire in a pan with vegetables, spices and seasoning, and simmer until tender. Blend the brains with a melted butter sauce and pour over the head. Garnish with slices of lemon.

Stewing.—This is the most inexpensive method of meat cookery and may take the form of a white or clear stew, *e.g.*, Irish stew, hot pot, or, a brown or white thickened stew, *e.g.*, stewed veal. For a clear stew place the meat direct in a pan with just enough water or stock to cover it. Season and add vegetables according to taste. For brown stew dip the meat in seasoned flour and fry in fat, then remove the meat and add sufficient flour to absorb the remaining fat in the pan and form a *roux*. Cook the *roux* until brown and add the stock which should be sufficient only to cover the meat. If onions are added these ought to be fried after the meat. A more elaborate stew is made by adding other ingredients, *e.g.*, mushrooms, vegetables, etc., together with special sauces.

A white stew is made with white stock, or milk and water, and the *roux* is not allowed to brown. In this case, the meat is not fried. A *blanquette* of veal is made by cutting the veal into small pieces. Place these in a pan with white stock to cover Peel two onions, stick with cloves, add one carrot and herbs. Bring to a boil and simmer for one hour. Strain off the liquor, thicken the latter with a flour liaison, cook and slightly cool. Add the yolk of an egg and chopped parsley. Pour over the veal.

Grilling or Broiling.—Trim off surplus fat and skin, beat into shape and, if necessary, tie with string. Oil the gridiron and heat it before using. Turn the meat frequently with tongs or two spoons. Do not use a fork. Grilled meats are usually served dry with *maître d'hôtel* butter (parsley, lemon juice and butter blended together), or merely moistened with the fat and juice which have run out of the meat.

Frying.—Unless the meat is minced and protected in batter, meat should always be "dry" fried, *i.e.*, in a frying pan. White internal organs, *e.g.*, sweetbreads, etc., ought to be scalded before cooking. Liver should be cut into thin strips; kidneys need skinning after washing. A "mixed grill" is commonly cooked by frying in place of grilling.

Meat is frequently reheated in the form of slices of meat warmed in good gravy, hash, curries (cold meat warmed in a curry sauce); or minced and formed into rissoles, etc. In all reheating the aim should be to avoid re-cooking. Judicious flavouring and careful cooking are the essentials in re-heated meat dishes.

Galantines.—These are cold meat dishes consisting of a mixture of several boned minced meats, poultry or game deprived of all gristle and skin and usually mixed with hard-boiled eggs and truffles to garnish. To prepare, pound all the ingredients except the garnishes in a mortar, add seasoning, shape into the desired form and tie in a floured cloth. Boil gently for two hours in water with pot herbs and seasoning to taste. After cooking remove cloth, reshape if necessary by pressing and rolling, and place under heavy weights. Finally, brush over with glaze. Trim off a slice from each end and garnish with fresh parsley.

Brawn.—Correctly speaking, brawn should be made from pig's or sheep's head but so-called brawns are made of rabbit, etc. Wash the head thoroughly, place in cold water to cover, bring to

a boil, add pot herbs and seasoning and simmer until the flesh leaves the bones. Skim while cooking. Cut up the cooked flesh into small pieces together with the tongue. Remove skin and gristle. Reduce the liquor to one half, and strain over the meat. Cool slightly and pour into a wetted mould. Spices may be added to brawns if desired.

See also COOKERY; GRAVIES; SAUCE. (J. A. St.)

MEATH, a county of Ireland, in the province of Leinster, bounded east by the Irish sea, south-east by Dublin, south by Kildare and Co. Offaly, west by Westmeath, north-west by Cavan and Monaghan, and north-east by Louth. Area 579,320 ac., or about 905 sq miles. Pop. (1926) 62,969.

In the north is a broken country of Silurian rocks with much igneous material, partly contemporaneous, partly intrusive, near Slane. Carboniferous limestone stretches from the Boyne valley to the Dublin border, giving rise to a flat plain especially suitable for grazing. Outliers of higher Carboniferous strata occur on the surface; but the Coal Measures have all been removed by denudation. The coast extends about 10 m., but there is no harbour of importance. Laytown is a small seaside resort, 5 m. S.E. of Drogheda. The Boyne enters the county at its south-western extremity, and flows north-east to Drogheda. At Navan it receives the Blackwater, which flows south-west from Cavan. Both these rivers are noted for their trout, and salmon are taken in the Boyne, which is navigable for barges as far as Navan whence a canal is carried to Trim. The Royal canal passes along the southern boundary from Dublin.

A district known as Meath (Midhe), including the present county as well as Westmeath and Longford, with parts of Cavan, Kildare and Co. Offaly was formed by Tuathal (*c.* 130) into a kingdom to serve as mensal land or personal estate of the Ard Ri or over-king of Ireland. Kings of Meath reigned until 1173, and their descendants claimed the title as late as the 15th century, but Hugh de Lacy was confirmed in the lordship of the country by Henry II. But though Meath was declared a county in the reign of Edward I. (1296), and though it came by descent into the possession of Edward IV., it was long before it was fully subdued and its boundaries clearly defined. In 1543 Westmeath was created a county apart from that of Meath, but as late as 1598 Meath was still regarded as a province by some, who included in it the counties Westmeath, East Meath, Longford and Cavan. Early in the 17th century it was at last established as a county, and no longer considered as a fifth province of Ireland.

There are two ancient round towers, the one at Kells and the other in the churchyard of Donaghmore, near Navan. By the river Boyne near Slane there is an ancient burial-place called Brugh, with 20 burial mounds, the largest of which is that of New Grange, a domed tumulus above a circular chamber. The mound is surrounded by remains of a stone circle, and the whole forms one of the most remarkable extant erections of its kind. Tara (*q.v.*) is the seat of a royal palace referred to by Thomas Moore. The more important monastic ruins are those of Duleek, said to have been the first ecclesiastical building in Ireland of stone and mortar; the extensive remains of Bective abbey; and those of Clonard, where also were a cathedral and a famous college. Of the old fortresses, the castle of Trim still presents an imposing appearance.

The soil is principally a rich deep loam on limestone gravel, but varies from a strong clayey loam to a light sandy gravel. Oats, potatoes and turnips are the principal crops. Cattle, sheep and poultry are increasing. Agriculture is almost the sole industry, but coarse linen is woven by hand-looms, and there are a few woollen manufactories. The main line of the Great Southern railway skirts the southern boundary, with a branch line north from Clonsilla to Navan and Kingscourt (Co. Cavan). From Kilmessan on this line a branch serves Trim and Athboy. From Drogheda (Co. Louth) a branch of the Great Northern railway crosses the county from east to west by Navan and Kells to Oldcastle. The administrative county of Meath returns three members to Dáil Eireann.

MEAT TRADE. The principal meat-exporting countries are Argentina, Australia, New Zealand and Uruguay. The total exports from these countries in 1927 were:—

	Beef	Mutton and lamb	Total
	Tons	Tons	Tons
Argentina	687,281	71,468	758,749
Australia	60,148	25,586	85,734
New Zealand	21,500	139,000	160,500
Uruguay	100,845	27,146	127,991

Brazil exported 24,183 tons of beef in 1927. Canada exports live cattle and sheep to the United States and in 1927 also sent 22,979 tons of beef to that country. To Great Britain in the same year she sent 8,263 head of cattle and 260 tons of frozen meat. South Africa is developing an export trade in beef and in 1927 shipped 6,044 tons, mostly to Italy. The quantity in that year was reduced by the effect of drought; in 1926 it reached 15,184 tons. Patagonia is an exporter of mutton and lamb and in 1927 shipped 27,760 tons.

The total quantity of frozen and chilled meat exported from all sources in 1927 is calculated at 1,256,900 tons. Of this quantity about one-fifth was produced in the British dominions and practically all the remainder in South America.

The total quantity imported into Great Britain and Ireland in 1927 was 949,304 tons, leaving about 300,000 tons, for all other importing countries.

English Meat Production.—It appears on the face of it, anomalous that while the quantity of meat imported into Great Britain is known, the quantity produced in Great Britain is unknown, and can only be approximately estimated. The reason, however, is obvious. The annual agricultural returns give the number of cattle and sheep in the country on a given day, but there are no returns of the number slaughtered in the course of the year, or of the quantity of meat which was thus produced.

The average numbers of animals sold for slaughter off farms in 1926–27 were estimated as:—cattle 1,285,000, calves 834,000, sheep and lambs 5,588,000; and the meat produced as—beef 360,250 tons, veal 32,400 tons, mutton and lamb 129,750 tons, making a total of 522,400 tons.

The following table shows the estimated total consumption in Great Britain and Ireland for the years 1922 and 1927, respectively:—

	1922	1927
	Tons	Tons
Beef		
Home-grown	767,300	819,900
Imported	556,229	673,136
Mutton and lamb		
Home-grown	254,600	303,300
Imported	292,438	276,168
	1,870,567	2,072,504
Deduct re-exports	44,597	23,859
	1,825,970	2,048,645

It will be seen that in 1927, 45% of the beef and 47½% of the mutton and lamb consumed were imported.

British Imports.—The total imports of meat in 1927 into Great Britain and Ireland, including carcasses of cattle imported alive, amounted to 949,304 tons. The quantities received from each of the main sources of supply are shown below:—

	Beef	Mutton and lamb	Total
	Tons	Tons	Tons
Argentina	577,916	76,824	654,740
Australia	32,137	31,398	63,535
Brazil	8,391	..	8,391
Chili (Patagonia)	..	13,815	13,815
New Zealand	16,543	136,866	153,409
North America	5,348	154	5,502
South Africa	352	..	352
Uruguay	29,418	15,863	45,281
Other countries	503	1,248	1,751
	670,608	276,168	946,776

Of the total imports of beef 77% is "chilled" and the remainder frozen, while all mutton and lamb comes in a frozen state.

It should be added that there is a considerable importation of tinned or canned beef and mutton. This is distinct from what is commonly termed the "meat trade" and is subject to different commercial conditions. In 1927 the imports of tinned or canned beef amounted to 52,025 tons and tinned or canned mutton and lamb to 2,535 tons.

The International Meat Trade.—The development of the vast commercial organization by which some 1¼ million tons of meat are collected, transported across the sea, and distributed, has taken place in little more than fifty years.

The American people were first confronted with their own continental problem and from the solution of this came the development of a meat export trade. In the development of the internal trade there were three stages. During the early settlement of the United States and down to about 1850 conditions were similar, all over the country, to those prevailing to-day in Great Britain where meat is produced near the centres of population. As the eastern States became more thickly populated cattle-raising moved west and droving to market became general, as in Great Britain. When the railway system rapidly developed the trade was organized and centralized at a few great collecting and distributing centres, of which Chicago was chief. The "packing industry" originated in America long previously when pork was "packed" in barrels for the West Indies. The term "packing-house products" or "packed products" thus came into use and was applied to all dressed meat. At first the industry was carried on only in the winter months but the artificial creation of winter conditions in the packing-houses during the hot summer months enabled them to continue operations without interruption throughout the year.

Refrigeration Systems.—Refrigeration, in the modern sense, was invented in 1861 but it was some years before it became satisfactory and reliable for purposes of transportation.

The successful transportation, under refrigerated conditions, of dressed meat from the packing-houses in the middle west to the eastern seaboard paved the way for shipment across the ocean. In 1874 frozen beef "as hard as stone" was sent to Smithfield market in boxes, but the consignment was small and the financial result unsatisfactory. The first shipment of "chilled" beef was made from New York on Oct. 1, 1875. It arrived in good condition and with this consignment the trade in chilled beef was established. By 1880 all the steamship lines running across the Atlantic were equipped with cold storage plants. The refrigerating equipment was at first somewhat crude, usually consisting of an ice box and fans to circulate the cold air. Another device was to pump a freezing mixture—salt and ice—along pipes between the hanging carcasses.

Argentina and Australia followed closely on the United States. In 1878 frozen meat was first brought from South America and in 1879 the first shipment was made from Sydney.

There were of course many difficulties to be surmounted and much experimental work was done before the methods of refrigeration were perfected. The creation of "freezing-works" soon followed and the meat is now all frozen or chilled before being placed in the cold chambers of the vessels for the voyage. But for about forty years the trade has been organized on its present lines and its magnitude and importance have steadily increased throughout the meat-producing countries of the world.

World's Future Meat Supplies.—One of the most marked results of the World War was to increase the demand for meat on the Continent. There are no statistics of any value on the point but there are indications that while the number of meat-consumers increases steadily, the average consumption per head tends to decrease. It is accepted as a sociological truism that as the standard of comfort rises dietary becomes more varied. The consumption of meat in working-class houses in England, for example, was probably greater in the middle of the 19th century than in the 20th century when there is a larger variety of food available. Nevertheless the total world demand for meat is almost certainly greater than at any previous period and increases annually.

During the World War there was, especially in Europe, a serious depletion of the stock of food animals. Exporting countries, such as Argentina, were heavily drawn upon to meet the enormous requirements of the Allied armies while the central Powers used up a large proportion of their flocks and herds as well as making heavy purchases from such neutral countries as were accessible. But since the war successful efforts have been made to repair the losses and replenish the stock. The International Agricultural Institute published statistics showing that the number of cattle in 1926 exceeded the number in 1913 by 12·2%, the comparative figures, by continents, being as follows in thousands:—

	1913	1926
Europe	137,861	139,477
N. and Central America	74,336	81,467
S. America	86,662	101,051
Asia	142,087	154,356
Africa	33,174	47,926
Oceania	13,856	23,089
	487,976	547,366

In addition to this increase of 60 millions in the number of cattle there was also in the same period an increase of 12½ millions in the number of sheep.

There is no reason to suppose that South America has yet come within measurable distance of the limits of its capacity for meat production. Vast areas of land suitable for carrying cattle and sheep still await development. The improvement of the native stock proceeds continuously and, in Argentina especially, the results of the importation of high-class bulls from Great Britain are widely evident. The process is necessarily slow but, apart from increased numbers, there is a steady increase in the output of meat per animal, as a more economic type replaces the old "scrub."

The geographical potentialities of Australia for rearing more cattle and sheep are immense but they are at present restricted by physical difficulties. There can be no doubt that these difficulties will in time be largely overcome and Australia's contribution to the world's supplies will be indefinitely increased. In South Africa the production and export of meat have been only very recently taken up with vigour, but there is little doubt that within the next two or three decades it will become an important contributor to the total supply.

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(R. H. R.)

IN THE UNITED STATES

Measured by the value of its output, the meat packing industry was the third largest industry in the United States, according to the latest census figures available (1925). The plant value of the products of this industry in 1925 was $3,050,286,291. Fresh meat products, consisting of beef, veal, mutton, lamb and pork represented by far the greatest proportion of this total. The value of the cured meat products also was large, exceeding three-fourths of a billion dollars.

These values, although somewhat smaller than in 1919 when prices were at a peak, probably are fairly representative of the annual volume of business of the meat packing industry. Illinois leads all the States in the value of products of the meat packing industry, with a volume valued in 1925 at $680,591,940. Kansas is second with products valued at the plant at $248,939,792. New York is third, with products valued at the plant at $233,901,277. Other States in which the plant value of the products of the meat packing industry exceeds $100,000,000 in value are Iowa, Missouri, Nebraska, Minnesota, Ohio, Pennsylvania and California.

The average consumption *per caput* of meat in the United States in 1927 was 139·3 pounds. This was divided among the different meats as follows: beef, 58; veal, 7·4; lamb, 5·4; pork, 68·5. In addition, consumption *per caput* of lard averaged 13·8 pounds.

This represents a daily consumption *per caput* of approximately 2½ oz. of beef; ⅓ oz. of veal; ¼ oz. of lamb, and 3 oz of pork, or a total of slightly more than 6 oz. A census of distribution, taken in 1927 in 11 cities, showed that the amount of money expended for meat and poultry (not including meat and poultry consumed in hotels and restaurants) averaged $27.18 *per caput*. The consumption of meat fluctuates somewhat from year to year, varying of course with the supply available and the export demand. Consumption *per caput* of meats and lard in 1927, which was 153·1 lb., compared closely with the average annual consumption *per caput* for the preceding 20 years, which was approximately 152 pounds. The total production of meat in the United States in 1927 was 16,872,000,000 pounds. Of this amount approximately 350,000,000 lb. were exported and the remainder consumed in the United States. Lard production in 1927 amounted to 2,356,000,000 pounds, of which 717,000,000 pounds, or 30%, were exported.

Millions of head of live stock are required to provide this enormous quantity of meat. According to estimates of the United States department of agriculture, the number of live stock on farms and ranges in the United States on Jan. 1, 1928, was as follows:

Cattle	55,696,000
Hogs	58,969,000
Sheep	44,545,000

Live stock producers receive for their meat animals an average of about $7,000,000 daily. The United States, the greatest live stock producing and meat consuming nation, has about 13% of the world's cattle; 7% of the world's sheep, and probably more than 25% of the world's hogs. In addition to its commercial importance, the live stock and meat industry is of peculiar economic significance. The reason for this is that live stock utilizes a large amount of grass, hay, etc., not suitable for consumption by man, and transform it into meat. Live stock also provides the outlet for a large proportion of the grain crops. Approximately 85% of the corn crop (maize), for example, is used for the feeding of live stock.

Imports of meat into the United States are relatively small, representing ordinarily less than 1% of the total supply. The export trade in meat products of the United States always has been important. Meat exports from the United States consist almost entirely of pork products. Although exports in 1928 were considerably lower than they were during the World War, in 1927 they exceeded 1,170,000,000 lb. in quantity and $172,500,000 in value. Among meat products, lard is the most important. Exports during 1927 approximated 700,000,000 lb., worth $92,000,000. Hams, shoulders and bacon also are important articles of export.

System of Distribution.—The bulk of the supply of live stock in the United States is produced west of the Mississippi river, and the bulk of the meat is consumed in the territory east of that river. This situation makes necessary an elaborate and efficient system of distribution. As the first step in this system, which distributes more than 50,000,000 lb. of meat daily, animals are shipped by rail or hauled by motor truck from farms to stockyards where packing plants are situated. These plants, of which there are several hundred, varying greatly in size, are located in all parts of the country, but are most numerous in such centres as Chicago, St. Louis, Kansas City, Omaha, St. Paul, St. Joseph, Missouri, Milwaukee, Indianapolis, Cleveland, Detroit, Cincinnati, Pittsburgh, Philadelphia, Baltimore and New York. From the packing plants the meat is distributed to all parts of the nation and of the world. This is accomplished through branch plants, branch selling houses, and "car routes" and by trucks. Goods are not sold directly to the consumer, but are sold to retailers. Branch selling houses sometimes do a limited amount of manufacturing, confining their operations largely to sausage-making and to the smoking of hams and bacon.

Car routes are operated in regions where the trade cannot conveniently or adequately be supplied from a plant or from branch houses. Ordinarily, car route orders are obtained by a salesman from dealers in a number of villages or cities in a given territory, after which the goods are packed at the plant in a refrigerator car for shipment. Motor truck routes are handled similarly. Many retailers obtain their meat supplies by truck from wholesale markets at plants or branch houses adjacent to their places of business.

The number of retailers who handle meat probably exceeds 200,000. According to the occupational census of 1920, 122,105 persons were employed as butchers and meat dealers. In addition, many grocers and delicatessen dealers sell meat. (W. Ha.)

MEAUX, a town of northern France, capital of an arrondissement in the department of Seine-et-Marne, and chief town of the agricultural region of Brie, 28 m. E.N.E. of Paris by rail. Pop. (1931) 12,965. In the Roman period Meaux was the capital of the Meldi, a small Gallic tribe, and in the middle ages of the Brie. It formed part of the kingdom of Austrasia, and afterwards belonged to the counts of Vermandois and Champagne, the latter of whom established important markets on the left bank of the Marne. Its communal charter, received from them, is dated 1179. The town suffered much during the Jacquerie, the peasants receiving a severe check there in 1358; during the Hundred Years' War; and also during the Religious Wars, in which it was an important Protestant centre. In September 1567 Meaux was the scene of an attempt made by the Protestants to seize the French king Charles IX., and his mother Catherine de' Medici. This doubtless had some share in influencing Charles to assent to the massacre of St. Bartholomew. It was the first town which opened its gates to Henry IV. in 1594. On the highroad for invaders marching on Paris from the east of France, Meaux saw its environs ravaged by the army of Lorraine in 1652, and was laid under heavy requisitions in 1814, 1815 and 1870. Not far from Meaux the two battles of the Marne took place in Sept. 1914 and in July 1918. The town proper stands on the right bank of the Marne; on the left bank lies the old suburb of Le Marché, with which it was united by a 16th century bridge. The cathedral of St. Stephen dates from the 12th to the 16th centuries, and was restored in the 19th century. The pulpit where Bossuet used to preach has been reconstructed. The episcopal palace (17th century) is built over a 13th century building, and is now used as a museum. North of the Cathedral is the Vieux Chapitre, a 13th century building.

Meaux has a considerable trade in agricultural products. The Canal de l'Ourcq, which surrounds the town, and the Marne furnish the means of transport. Meaux is the seat of a bishopric dating from the 4th century, and has a sub-prefecture, and tribunals of first instance and of commerce.

MECCA (Arab, *Makkah*), the chief town of the Hejāz in Arabia and the great holy city of Islām. It is situated about 45 m. due E. of Jidda, its Red Sea port, and about half way between the Gulf of Akaba and Bab-el-Mandeb. The city lies in a hollow among the hills which form part of the uptilted western edge of the ancient Arabian plateau. To the west the land falls steeply to the low coastal strip bordering the Red sea. The basin in which the city lies is about 2 m. long and ½ m. broad, and forms part of a north to south valley. The high lands around include Jebel Kadâ, Jebel Laala, Jebel Gaygaân, Jebel Kudâ and Jebel Khandama. These vary in height, but are all over 1,500 feet. Jebel Khandama is the highest, being about 3,000 ft. above sea-level. Minor heights, the lower spurs of the former, actually overlook the city. It is said in the Koran (*Sur.* xiv. 40) that Mecca lies in a sterile valley, and the old geographers observe that the whole Haram or sanctuary around the city is almost without cultivation or date palms, while fruit trees, springs, wells, gardens and green valleys are found immediately beyond. But Mecca owed its early importance to the fact that it was a great focus of routes for the caravan trade of the desert. It was probably a station on the great incense route, and thus Ptolemy may have learned the name, which he writes Makoraba. At all events, long before Mohammed we find Mecca established in the twofold quality of a commercial centre and a privileged holy place, surrounded by an inviolable territory (the Haram), which was not the sanctuary of a single tribe but a place of pilgrimage, where religious observances were associated with a series of annual fairs at different points in the vicinity. Indeed,

in a city with the nomad hordes without, commerce was possible only under the sanction of religion, and through the provisions of the sacred truce which prohibited war for four months of the year, three of these being the month of pilgrimage, with those immediately preceding and following. The first of the series of fairs in which the Meccans had an interest was at Okaz, on the easier road between Mecca and Taif, where there was also a sanctuary, and from it the visitors moved on to points still nearer Mecca (Majanna, and finally Dhul-Majāz, on the flank of Jebel Kabkab behind Arafa) where further fairs were held, culminating in the special religious ceremonies of the great feast at Arafa, Quzah (Mozdalifa), and Mecca itself. The system of intercalation in the lunar calendar of the early Arabs was designed to secure that the feast should always fall at the time when the hides, fruits and other merchandise were ready for market, and the Meccans, who knew how to attract the Bedouins by hospitality, bought up these wares in exchange for imported goods, and so became the leaders of the international trade of Arabia. Their caravans traversed the length and breadth of the peninsula. Syria, and especially Gaza, was their chief goal. The Syrian caravan intercepted, on its return, at Badr. (*See* MOHAMMED.) The great desert market had received merchants from many lands, while in the ancient Ka'ba were installed deities representative, possibly, of the various groups of visiting merchants. It is said that at the time of the Prophet the Ka'ba contained, among others, an image of the Virgin and the Child Jesus. As so often happens in great marts, ideas as well as merchandise were exchanged, and with time there grew up the idea that these minor deities had much in common: the universal overcame the local. To this ancient and sacred mart came Mohammed, with his vision of the unity of God, learnt, it seems, from the Hebrew prophets, and here the vision took shape, to be carried to the ends of the earth by the swords of his followers.

The victory of Mohammedanism made a vast change in the position of Mecca. The merchant aristocracy became satraps or pensioners of a great empire; but the seat of dominion was removed beyond the desert, and though Mecca and the Hejāz strove for a time to maintain political as well as religious predominance, the struggle was vain, and terminated on the death of Ibn Zubair, the Meccan pretendant to the caliphate, when the city was taken by Hajjāj (A.D. 692). The sanctuary and feast of Mecca received, however, a new prestige from the victory of Islām. Purged of elements obviously pre-Islāmic, the new religion became grafted on the life of the city, the Ka'ba became the holiest site, and the pilgrimage the most sacred ritual observance of Mohammedanism, drawing worshippers from so wide a circle that the confluence of the petty traders of the desert was no longer the main feature of the holy season.

In the middle ages this trade was much more important than it is now. Ibn Jubair (ed. Wright, p. 118 *seq.*) in the 12th century describes the mart of Mecca in the eight days following the feast as full of gems, unguents, precious drugs, and all rare merchandise, from India, 'Iraq, Khorāsān, and every part of the Muslim world. Since the fall of Ibn Jubair the political position of Mecca has always been dependent on the movements of the greater Mohammedan world. In the splendid times of the caliphs immense sums were lavished upon the pilgrimage and the holy city; and conversely the decay of the central authority of Islām brought with it a long period of faction, wars and misery, in which the most notable episode was the sack of Mecca by the Carmathians at the pilgrimage season of A.D. 930. The victors carried off the "black stone," which was not restored for 22 years, and then only for a great ransom, when it was plain that even the loss of its palladium could not destroy the sacred character of the city. Under the Fatimites Egyptian influence began to be strong in Mecca; it was opposed by the sultans of Yemen, while native princes claiming descent from the Prophet —the Hāshimite amīrs of Mecca, and after them the amīrs of the house of Qatāda (since 1202)—attained to great authority and aimed at independence; but soon after the final fall of the Abbasids the Egyptian overlordship was definitely established by sultan Bībars (A.D. 1269). The Turkish conquest of Egypt transferred the supremacy to the Ottoman sultans (1517), who treated Mecca with much favour, and during the 16th century executed great works in the sanctuary and temple. The Ottoman power, however, became gradually almost nominal, and that of the amīrs or sherīfs increased in proportion, culminating under Ghālib, whose accession dates from 1786. Then followed the wars of the Wahhābīs (*see* ARABIA and WAHHĀBĪS) and the restoration of Turkish rule by the troops of Mehemet 'Ali. By him the dignity of sherīf was deprived of much of its weight, and in 1827 a change of dynasty was effected by the appointment of Ibn 'Aun. Afterwards Turkish authority again decayed. When the great Mohammedan sultanates had become too much occupied in internecine wars to maintain order in the distant Hejāz, those branches of the Hassanids which, from the beginning of Islām, had retained rural property in Arabia usurped power in the holy cities and the adjacent Bedouin territories. About A.D. 960 they established a sort of kingdom with Mecca as capital. The influence of the princes of Mecca has varied from time to time, according to the strength of the foreign protectorate in the Hejāz or in consequence of feuds among the branches of the house, until about 1882 it was for most purposes much greater than that of the Turks. During the last quarter of the 19th century Turkish influence became preponderant in western Arabia, and the railway from Syria to the Hejāz tended to consolidate the sultan's supremacy. Difficult times for the Turkish power arose with the revival of the Wahhābīs movement after 1912. The revolt of King Husayn of the Hejāz during the World War of 1914–18 completed the overthrow of the Turks. The period 1919–1925 saw the rapid rise to power of Ibn Sa'ud and the Wahhābīs and the overthrow of the Hâshimite Government. After a fight at Hadda in the Taif mountains, Ibn Sa'ud occupied Mecca, without bloodshed, in Oct. 1924.

The City.—The hills east and west of Mecca, which are partly built over and rise several hundred feet above the valley, so enclose the city that the ancient walls only barred the valley at three points, where three gates led into the town. In the time of Ibn Jubair the gates still stood though the walls were ruined, but now the gates have only left their names to quarters of the town. At the northern or upper end was the Bāb el Mā'lā, or gate of the upper quarter, whence the road continues up the valley towards Minā and Arafa as well as towards Zeima and the Nejd. Beyond the gate, in a place called the Hajūn, is the chief cemetery, commonly called el Mā'lā, and said to be the resting-place of many of the companions of Mohammed. Here a cross-road, running over the hill to join the main Medīna road from the western gate, turns off to the west by the pass of Kadā, the point from which the troops of the Prophet stormed the city (A.H. 8). The lower or southern gate, at the Masfala quarter, opened on the Yemen road, where the rain-water from Mecca flows off into an open valley. Beyond, there are mountains on both sides; on that to the east, commanding the town, is the great castle, a fortress of considerable strength. The third or western gate, Bāb el-Omra (formerly also Bāb el-Zāhir, from a village of that name), lay almost opposite the great mosque, and opened on a road leading westwards round the southern spurs of the Red mountain. This is the way to Wādi Fātima and Medīna, the Jedda road branching off from it to the left. Considerable suburbs now lie outside the quarter named after this gate; in the middle ages a road led for some miles through partly cultivated land with good wells, as far as the boundary of the sacred territory and gathering place of the pilgrims at Tanīm.

The length of the sinuous main axis of the city from the farthest suburbs on the Medīna road to the suburbs in the extreme north, now frequented by Bedouins, is, according to Burckhardt, 3,500 paces. About the middle of this line the longitudinal thoroughfares are pushed aside by the vast courtyard and colonnades which compose the great mosque. The mosque is enclosed by houses with windows opening on the arcades and commanding a view of the Ka'ba. Immediately beyond these, on the side facing Jebel Abu Kobais, a broad street runs south-east and north-west across the valley. This is the Mas'ā (sacred course) between the eminences of Safā and Marwa,

and has been from very early times one of the [illegible] and the centre of Meccan life. The other chief [illegible] are also near the mosque in smaller streets.

The houses of ancient Mecca pressed close up to the Ka'ba, the noblest families who traced their descent from Kosai the reputed founder of the city, having their dwellings immediately round the sanctuary. To the north of the Ka'ba was the Dar el-Nadwa, or place of assembly of the Koreish. The multiplication of pilgrims after Islām soon made it necessary to clear away the nearest dwellings and enlarge the place of prayer around the Ancient House. Omar, Othmān and Ibn Jubair had all a share in this work. The city is fortunate in having a good supply of water, and water works were laid down by Sultan Selim II. in 1571. Heavy rains or cloudbursts on the hills around have the effect of seriously flooding the city, and in spite of the building of various dams it is no uncommon sight to see the Sûk es-Saghîr, one of the main streets, a real water course. Many of the houses in Mecca are built of a fine dark grey granite, which is obtained near Jebel Umar. During the period before the World War of 1914–18 the Turks did much to improve the streets and the general condition of the city and its population, and prosperity greatly increased. To the eastward of the Haram, in a small depression known as Jiyâd, was the Turkish residential area and it still remains a good quarter of the city. The population of the city at present (1929) is estimated between 50,000 and 60,000. The only architectural feature is the great mosque (*see* below), which is at the same time the university hall, where, between two pilgrim seasons, lectures are delivered on Mohammedan law, doctrine and connected branches of science. A poorly provided public library is open to the use of students. The madrassehs or buildings around the mosque, originally intended as lodgings for students and professors, have long been let out to rich pilgrims. There are baths, ribats or hospices for poor pilgrims from India, Java, etc., a hospital and a public kitchen for the poor.

The Great Mosque and the Kaʻba.—Long before Mohammed the chief sanctuary of Mecca was the Kaʻba, a rude stone building without windows, and having a door 7ft. from the ground. The Kaʻba has been rebuilt more than once since Mohammed purged it of idols and adopted it as the chief sanctuary of Islām, but the old form has been preserved, except in secondary details. It is essentially a pre-Islāmic temple, adapted to the worship of Islām on the basis of the story that it was built by Abraham and Ishmael by divine revelation as a temple of pure monotheism, and that it was only temporarily perverted to idol worship from the time when ʻAmr ibn Lohai introduced the statue of Hobal from Syria till the victory of Islām. The chief object of veneration is the black stone, which is fixed in the external angle facing Safā in the south-east corner. Its technical name is the black corner, the others being named the Yemen (south-west), Syrian (north-west), and ʻIraq (north-east) corners, from the lands to which they approximately point. The black stone is a small dark mass with an aspect suggesting volcanic or meteoric origin, fixed at such a height that it can be conveniently kissed. The history of this heavenly stone, given by Gabriel to Abraham, does not conceal the fact that it was originally the most venerated of a multitude of idols and sacred stones which stood all round the sanctuary in the time of Mohammed. The Prophet destroyed the idols, but he left the characteristic form of worship—the *ṭawāf*, or sevenfold circuit of the sanctuary, the worshipper kissing or touching the objects of his veneration—and besides the black stone he recognized the so-called "southern" stone, the same presumably as that which is still touched in the ṭawāf at the Yemen corner (*Muh. in Med.*, pp. 336, 425). The ceremony of the ṭawāf and the worship of stone was common to Mecca with other ancient Arabian sanctuaries. It is still the first duty of one who has returned to the city or arrived there as a pilgrim.

Islām associated legends with those spots within the Kaʻba previously sacred to older cults; such are the *Multazam*, on the east side, between the black and ʻIraq corners, where prayer should be offered; the *Maʻjan* ("kneading place") where Abraham is said to have stood to build the Kaʻba, and the *Ḥijr* on the north-side which is included in the ṭawāf, and two slabs of *verde antico* within it are called the graves of Ishmael and Hagar, and are places of acceptable prayer. Even the golden or gilded *mīzāb* (water-spout) that projects into the Ḥijr marks a place where prayer is heard, and another such place is the part of the west wall close to the Yemen corner.

The feeling of religious conservatism which has preserved the structural rudeness of the Kaʻba did not prohibit costly surface decoration. In Mohammed's time the outer walls were covered by a veil (or *kiswa*) of striped Yemen cloth. The caliphs substituted a covering of figured brocade, and the Egyptian Government still sends with each pilgrim caravan from Cairo a new kiswa of black brocade, adorned with a broad band embroidered with golden inscriptions from the Korān, as well as a richer curtain for the door. The door of two leaves, with its posts and lintel, is of silver gilt. Ibn Jubair describes the floor and walls as overlaid with richly variegated marbles, and the upper half of the walls as plated with silver, thickly gilt, while the roof was veiled with coloured silk. Modern writers describe the place as windowless, but Ibn Jubair mentions five windows of rich stained glass from ʻIraq. Between the three pillars of teak hung 13 silver lamps. A chest in the corner to the left of one entering contained Korāns, and at the ʻIraq corner a space was cut off enclosing the stair that leads to the roof. The door to this stair (called the door of mercy—Bāb el-Raḥma) was plated with silver by the caliph Motawakkil. Here, in the time of Ibn Jubair, the *Maqām* or standing stone of Abraham was usually placed for better security, but brought out on great occasions.

The great founder of the mosque in its present form, with its spacious area and deep colonnades, was the caliph Mahdī, who spent enormous sums in bringing costly pillars from Egypt and Syria. The work was still incomplete at his death in A.D. 785, and was finished in less sumptuous style by his successor. Subsequent repairs and additions, extending down to Turkish times, have left little of Mahdī's work untouched, though a few of the pillars probably date from his days.

After the Kaʻba the principal points of interest in the mosque are the well Zamzam and the Maqām Ibrāhīm. The former is a deep shaft enclosed in a massive vaulted building paved with marble, and, according to Mohammedan tradition, is the source (corresponding to the Beer-lahai-roi of Gen. xvi. 14) from which Hagar drew water for her son Ishmael. The legend tells that the well was long covered up and rediscovered by ʻAbd al-Moṭṭalib, the grandfather of the Prophet. Sacred wells are familiar features of Semitic sanctuaries. The Maqām Ibrāhīm is also connected with a relic of pre-Islamic tradition, the ancient holy stone which once stood on the Maʻjan, and is said to bear the prints of the patriarch's feet. The legend seems to have arisen from a misconception, the Maqām Ibrāhīm in the Korān meaning the sanctuary itself; but the stone itself is certainly very ancient.

Safā and Marwa.—In religious importance these two points or "hills," connected by the Masʻā, stand second only to the Kaʻba. Safā is an elevated platform surmounted by a triple arch, and approached by a flight of steps. It lies south-east of the Kaʻba, facing the black corner, and 76 paces from the "Gate of Safā," which is architecturally the chief gate of the mosque. Marwa is a similar platform, formerly covered with a single arch, on the opposite side of the valley. It stands on a spur of the Red mountain called Jebel Kuayḳian. The course between these two sacred points is 493 paces long, and the religious ceremony called the "saʻy" consists in traversing it seven times, beginning and ending at Safā. The lowest part of the course, between the so-called green milestones, is done at a run. This ceremony is part of the omra and is generally said to be performed in memory of Hagar, who ran to and fro between the two eminences, vainly seeking water for her son. The observance, however, is certainly of pre-Islamic origin; and at one time there were idols on both the so-called hills. (*See* especially Azraqī, pp. 74, 78.)

The Ceremonies and the Pilgrimage.—Before Islām the Kaʻba was the local sanctuary of the Meccans, where they prayed and did sacrifice, where oaths were administered and hard cases submitted to divine sentence according to the immemorial custom of Semitic shrines. But, besides this, Mecca was already a place

of pilgrimage. The custom had already such a hold on the Arabs, that Mohammed could not afford to sacrifice it to an abstract purity of religion, and thus the old usages were transplanted into Islām in the double form of the omra or vow of pilgrimage to Mecca, which can be discharged at any time, and the ḥajj or pilgrimage at the great annual feast. The latter closes with a visit to the Kaʿba, but its essential ceremonies lie outside Mecca, at the neighbouring shrines where the old Arabs gathered before the Meccan fair.

The omra begins at some point outside the Ḥaram (or holy territory), generally at Tanim, both for convenience sake and because Ayesha began the omra there in the year 10 of the Hegira. The pilgrim enters the Ḥaram in the antique and scanty pilgrimage dress (iḥrām), consisting of two cloths wound round his person in a way prescribed by ritual. His devotion is expressed in shouts of "Labbeyka" (a word of obscure origin and meaning); he enters the great mosque, performs the ṭawāf and the saʿy and then has his head shaved and resumes his common dress. This ceremony is now generally combined with the ḥajj, or is performed by every stranger or traveller when he enters Mecca, and the iḥrām (which involves the acts of abstinence already referred to) is assumed at a considerable distance from the city. But it is also proper during one's residence in the holy city to perform at least one omra from Tanim in connection with a visit to the mosque of Ayesha there. The triviality of these rites is ill concealed by the legends of the saʿy of Hagar and of the ṭawāf being first performed by Adam in imitation of the circuit of the angels about the throne of God. There is a tradition that the Kaʿba was a temple of Saturn (Shahrastānī, p. 431); perhaps the most distinctive feature of the shrine may be sought in the sacred doves which still enjoy the protection of the sanctuary. These recall the sacred doves of Ascalon (Philo vi. 200 of Richter's ed.), and suggests Venus-worship as at least one element (*cf.* Herod i. 131, iii. 8; Ephr. Syr., *Op. Syr.* ii. 457).

To the ordinary pilgrim the omra has become so much an episode of the ḥajj that it is described by some European pilgrims as a mere visit to the mosque of Ayesha; a better conception of its original significance is got from the Meccan feast of the seventh month (Rajab), described by Ibn Jubair from his observations in A.D. 1184. Rajab was one of the ancient sacred months, and the feast, which extended through the whole month and was a joyful season of hospitality and thanksgiving, no doubt represents the ancient feasts of Mecca more exactly than the ceremonies of the ḥajj, in which old usage has been overlaid by traditions and glosses of Islām. The omra was performed by crowds from day to day, especially at new and full moon. The new moon celebration was nocturnal; the road to Tanim, the Masʿā, and the mosque were brilliantly illuminated; and the appearing of the moon was greeted with noisy music. An Arab market was held, where the Bedouins of the Yemen mountains came in thousands to barter their cattle and fruits for clothing, and deemed that to absent themselves would bring drought and cattle plague in their homes. Though ignorant of the legal ritual and prayers, they performed the ṭawāf with enthusiasm, throwing themselves against the Kaʿba and clinging to its curtains. They also entered the Kaʿba. The 29th of the month was the feast day of the Meccan women.

The central and essential ceremonies of the ḥajj or greater pilgrimage are those of the day of Arafa, the 9th of the "pilgrimage month" (Dhuʾl Ḥijja), the last of the Arab year; and every Muslim who is his own master, and can command the necessary means, is bound to join in these once in his life, or to have them fulfilled by a substitute on his behalf and at his expense. Neglect of many other parts of the pilgrim ceremonial may be compensated by offerings, but to miss the "stand" (*woqūf*) at Arafa is to miss the pilgrimage. Arafa or Arafat is a space, artificially limited, round a small isolated hill called the Hill of Mercy, a little way outside the holy territory, on the road from Mecca to Taif. The road is first northwards along the Mecca valley and then turns eastward. It leads through the straggling village of Mina, occupying a long narrow valley (Wādi Mina), two to three hours from Mecca, and thence by the mosque of Mozdalifa over a narrow pass opening out into the plain of Arafa, which is an expansion of the great Wādi Naman, through which the Taif road descends from Mount Kara. The lofty and rugged mountains of the Hodheyl tower over the plain on the north side and overshadow the little Hill of Mercy, which is one of those bosses of weathered granite so common in the Hejāz. Arafa lay quite near Dhul-Majaz, where, according to Arabian tradition, a great fair was held from the 1st to the 8th of the pilgrimage month; and the ceremonies from which the ḥajj was derived were originally an appendix to this fair. Now, on the contrary, the pilgrim is expected to follow as closely as may be the movements of the prophet at his "farewell pilgrimage" in the year 10 of the Hegira (A.D. 632). He therefore leaves Mecca in pilgrim garb on the 8th of Dhuʾl Ḥijja, called the day of *tarwīya* (an obscure and pre-Islamic name), and, strictly speaking, should spend the night at Mina. It is now, however, customary to go right on and encamp at once at Arafa. The night should be spent in devotion, but the coffee booths do a lively trade, and songs are as common as prayers. In the afternoon of the next day the essential ceremony begins; it consists simply in "standing" on Arafa shouting "Labbeyka" and reciting prayers and texts till sunset. After the sun is down the vast assemblage breaks up, and a rush (technically *ifāḍa, dafʿ, nafr*) is made to Mozdalifa, where the night prayer is said and the night spent. Before sunrise next morning (the 10th) a second "stand" like that on Arafa is made for a short time by torchlight round the mosque of Mozdalifa, but before the sun is fairly up all must be in motion in the second *ifāḍa* towards Mina. The day thus begun is the "day of sacrifice," and has four ceremonies—(1) to pelt with seven stones a cairn (*jamrat al ʿaqaba*) at the eastern end of W. Mina, (2) to slay a victim at Mina and hold a sacrificial meal, part of the flesh being also dried and so preserved, or given to the poor, (3) to be shaved and so terminate the *iḥrām,* (4) to make the third *ifāḍa, i.e.,* go to Mecca and perform the ṭawāf and saʿy (*ʿomrat al-ifāḍa*), returning thereafter to Mina. The sacrifice and visit to Mecca may, however, be delayed till the 11th, 12th or 13th. These are the days of Mina, a fair and joyous feast, with no special ceremony except that each day the pilgrim is expected to throw seven stones at the *jamrat al ʿaqaba,* and also at each of two similar cairns in the valley. The stones are thrown in the name of Allah, and are generally thought to be directed at the devil. This is, however, a custom older than Islām, and a tradition in Azraqī, p. 412, represents it as an act of worship to idols at Mina. As the stones are thrown on the days of the fair, it is not unlikely that they have something to do with the old Arab mode of closing a sale by the purchaser throwing a stone (Bīrūnī, p. 328). The pilgrims leave Mina on the 12th or 13th, and the ḥajj is then over. (*See* further ISLAM.)

The statistics of the pilgrimage cannot be given with certainty and vary much from year to year. For a *fatwa* or judicial decision may be obtained that it is not obligatory for the Muslim to journey to Mecca when the routes are in the hands of hostile forces. Estimates of the crowd vary from 50,000 to 70,000. In these vast assemblies, with little sanitary accommodation, infectious diseases spread rapidly.

BIBLIOGRAPHY.—Besides the Arabic geographers and cosmographers, we have Ibn ʿAbd Rabbih's description of the mosque, early in the 10th century (ʿ*Iḳd Farīd,* Cairo ed., iii. 362 *sqq.*), but above all the admirable record of Ibn Jubair (A.D. 1184), by far the best account extant of Mecca and the pilgrimage. It has been much pillaged by Ibn Baṭūta. The Arabic historians are largely occupied with fabulous matter as to Mecca before Islām; for these legends the reader may refer to C. de Perceval's *Essai.* How little confidence can be placed in the pre-Islamic history appears very clearly from the distorted accounts of Abraha's excursion against the Hejāz, which fell but a few years before the birth of the Prophet, and is the first event in Meccan history which has confirmation from other sources. *See* Nöldeke's version of Ṭabarī, p. 204 *sqq.* For the period of the Prophet, Ibn Hishām and Wāḳidī are valuable sources in topography as well as history. Of the special histories and descriptions of Mecca published by Wüstenfeld (*Chroniken der Stadt Mekka,* 3 vols., 1857–49, with an abstract in German, 1861), the most valuable is that of Azraqī. It has passed through the hands of several editors, but the oldest part goes back to the beginning of the 9th Christian century. Kutbeddin's history (vol. iii. of the *Chroniken*) goes down with the additions of his nephew to A.D. 1592.

For European descriptions of Mecca from personal observation *see* Burckhardt's *Travels in Arabia* (cited above from the 8vo ed., 1829). *The Travels of Aly Bey* (Badia, London, 1816) describe a visit in 1807; Burton's *Pilgrimage* (3rd ed., 1879) often supplements Burckhardt;

Von Maltzan's *Wallfahrt nach Mekka* (1865) is lively but very slight. 'Abd el-Razzāq's report to the Government of India on the pilgrimage of 1858 is specially directed to sanitary questions; C. Snouck-Hurgronje, *Mekka* (2 vols. and a collection of photographs, The Hague, 1888–89), gives a description of the Meccan sanctuary and of the public and private life of the Meccans as observed by the author during a sojourn in the holy city in 1884–85 and a political history of Mecca from native sources from the Hegira till 1884. Eldon Rutter, *The Holy Cities of Arabia*, vol. i. (1928), is the most recent work. For the pilgrimage *see* also Snouck-Hurgronje, *Het Mekkaansche Feest* (1880).

MECHANICAL DRAWING: *see* DRAWING, ENGINEERING.

MECHANICAL ENGINEER. By the beginning of the 19th century the development of the steam engine had resulted in a large increase in the size and number of machines in operation and the factory system was beginning to appear. The millwright and smith were not competent to devise and construct the new machines and consequently the profession of mechanical engineer came into being. The name of mechanical engineer became common about the middle of the century. The British Institution of Mechanical Engineers was founded in 1847. About 1890 the field of mechanical engineering was restricted by the separation of the important field of electrical engineering. The field of the mechanical engineer comprises (1) power generation and transmission, (2) transportation of both men and goods, including railway, marine, automobile and aeronautic, as well as hoisting, conveying and pumping and (3) production, which includes machine tools as well as the final products of manufacture. Functionally considered, the work of the mechanical engineer may be classified as design, construction, operation, research and investigation, maintenance and sales. The great majority of mechanical engineers are employees of organizations engaged in production or transportation; a small percentage only is engaged in the private practice of their profession as consultants. In the United States, the education of the mechanical engineer is normally by a four-year undergraduate course in a degree-granting college or university. On completion of the course, a large percentage of the students enter the employment of industrial organizations as apprentices for a period of one or two years; in most of the larger companies this work is organized so as to give opportunities for gaining experience in various departments, with about three months spent in each. In Great Britain, there are only 14 universities which grant degrees in engineering and only a small fraction of the engineers are trained in them. The normal preparation for the profession is by a five-year apprenticeship. Theoretical instruction is obtained by evening work at local technical institutions, of which there are about 150. These institutions usually grant diplomas on the completion of a prescribed course. In Scotland the university instruction occupies about six months of the year and it is customary for the students to alternate between study and work during the apprenticeship. In England, this alternation is not usual, and apprenticeship follows the completion of the university work. In Germany the conditions are in general similar to those in Great Britain.

(L. S. MA.)

MECHANICAL HANDLING. Before mechanical handling became an important operation in all industries a variety of appellations were assigned to machines for such purposes. At first the designation most favoured was "labour saving devices," because it was applicable both to the mechanical and to the economical aspect; this designation has now been practically superseded by the one which heads this article. The term was coined in America about the year 1900, but since 1920 it has been replaced there by the term "materials-handling."

The mechanical plant of a modern factory consists generally of two classes of machinery in addition to the power plant; that for manufacturing a certain commodity, usually by a complex series of operations; and the handling machinery which brings the raw material to the factory, moves it automatically from process to process, and finally conveys the finished commodity to the warehouse or forwarding depôt. The manufacturing process increases the intrinsic value of the goods; but the mechanical handling operations do not add to the value of the product and such work must therefore be performed at a minimum of expense.

Mechanical handling devices are divided into two main sections, viz., continuous and intermittent. The former convey the material in a comparatively small but uniform and uninterrupted stream, while the latter convey larger units in intermittent succession. Continuous devices are subdivided into appliances for lifting material *i.e.*, bucket elevators and appliances for moving material horizontally, *i.e.*, conveyors.

Bucket Elevators.—Bucket elevators, though always included under continuous devices, are not absolutely continuous on account of the almost imperceptible hiatus between the small successive loads. They consist essentially of an endless belt, chain, or chains, which pass over an upper and lower terminal, and to which suitably shaped buckets are attached in close succession. Such devices may be used vertically, running at a high speed, for relatively light material, such as grain. For minerals a slower speed is necessary and the upper or delivery end of the elevator must therefore be disposed at an incline in order to ensure clean delivery, *i.e.*, without spilling.

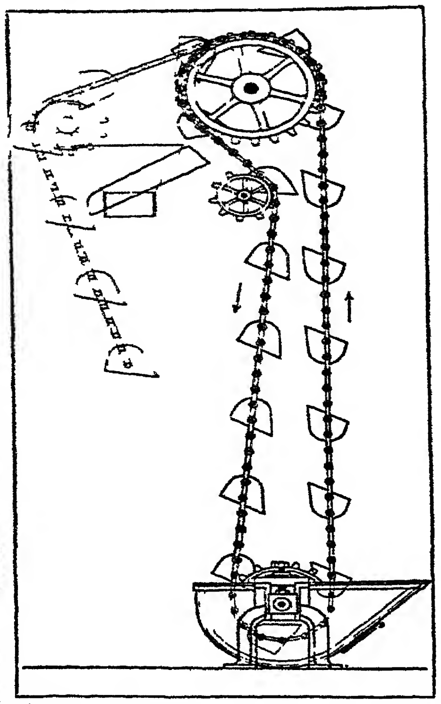


FIG. 1.—VERTICAL ELEVATOR, FROM WHICH CLEAN DELIVERY IS ENSURED BY TWO ALTERNATE APPLICATIONS OF A JOCKEY PULLEY

If the inclined disposition is not suitable for the site a jockey pulley can be used to attain the same end, as shown in fig. 1. But for this purpose two endless chains are necessary, which support the buckets between them.

In the following brief descriptions of continuous handling devices no reference is made to the inclines up or down which they may negotiate. (For this information *see* diagram, fig. 9.)

TYPES OF CONVEYORS

One of the oldest conveyor devices is the *worm* or *screw* conveyor. It consists of a stationary trough of wood or steel plates, in which a helix rotates and pushes the material fed into it from end to end. Its capacity is relatively small, it is apt to injure friable materials, and its driving power is high; on the other hand, where mixing of the material is essential, as in the handling of poultry food, flour, etc., the worm is quite good; it has the further advantage that material can be fed on from any number of points and can likewise be withdrawn at any alternative point

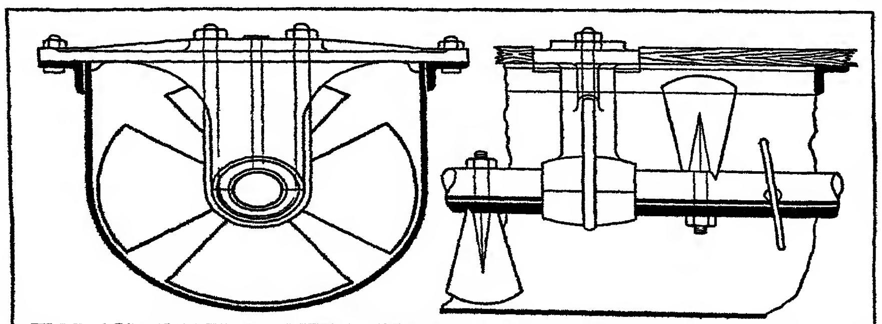


FIG. 2.—PORTION OF A PADDLE WORM, SHOWING STEEL TROUGH AND INTERMEDIATE BEARING

or points, through openings in the base of the trough, which can be closed by sliding gates when not required. There are a number of types of the worm conveyor, one of which is shown in fig. 2.

The *pushplate, scraper* or *drag* conveyor is similar in principle to the foregoing, but the material is pushed along by an endless running chain or chains, to which are attached dragging or pushing plates. This device may be used for handling larger quantities than the worm conveyor, but it shares its advantages as well

as disadvantages, so far as power consumption and possible injury to the material is concerned. It is fed similarly to the worm, in and out at any number of points, when the idle return run of the chain passes over the top of the working run. In fig. 3 this is illustrated diagrammatically.

The *U-link* conveyor is an obvious modification of this type, in which the chain itself is so formed that it will drag the material

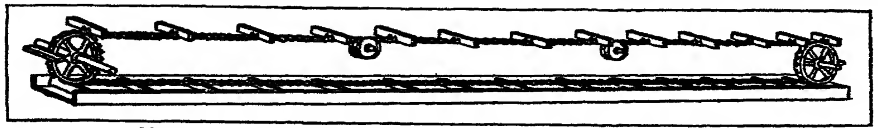


FIG. 3.—SIMPLE TYPE OF PUSH-PLATE CONVEYOR

along without any other attachment. The links are in the form of the letter U.

The *De Brouwer* or *push-bar* conveyor is widely employed in gas works for handling incandescent coke. This always runs in a trough filled with water. The trough is made with a renewable cast-iron base and the two chains, one on either side, which support the pushing bars, are protected in recesses, and thus do not come in contact with the coke.

All types of these conveyors, including those yet to be described, are fitted with power-driven sprockets at their delivery ends, and at their other ends with similar terminal sprockets arranged with tension take-ups for keeping the chains taut.

Band or Belt Conveyors.—Types of conveyors will now be considered where the material is carried on top of the conveying device, which method is more gentle. The foremost of these is the band or belt conveyor, illustrated diagrammatically in fig. 4. This device consists essentially of two terminal drums over which an endless band travels, supported on its carrying as well as on its return run by idler rollers, pitched closely on the loaded run and two or three times the distance apart on the return run. Such idlers are ordinary small diameter rollers of steel in some instances, as, for example, for handling goods in packing cases; or more frequently a combination of three or more shorter rollers which give the band a trough-like shape when bulk material such as grain or coal is handled in large quantities. The idlers for the conveying strand may be as close as 2 to 3 ft. apart, or even up to a distance of 6 feet.

The belt or band itself can be made of various materials, that being chosen which will best suit the goods handled. Compound cotton-duck-and-rubber belting is most frequently employed. The pulley side has a rubber coating of about $\frac{1}{16}$ in., while on the edges and working side are thicker layers of rubber, finally the whole is vulcanized. For light work, cotton belting of the Gandy type may suffice, and the idlers are sometimes replaced by a board of hard wood. Balata belting is also used, as well as woven wire

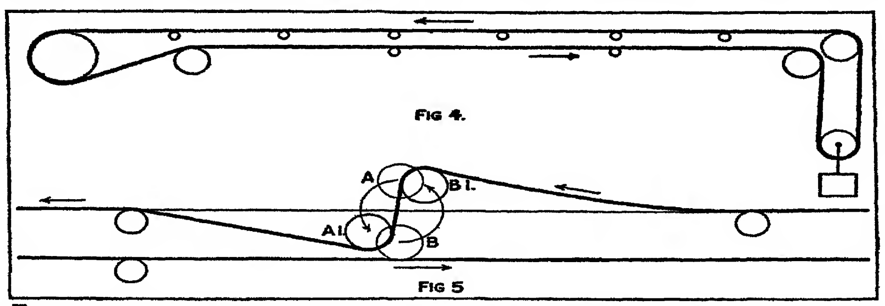


FIG. 4.—DIAGRAM SHOWING GENERAL ARRANGEMENT OF BAND CONVEYOR
FIG. 5.—ACTION OF A THROW-OFF CARRIAGE, SHOWN DIAGRAMMATICALLY

and even Swedish charcoal steel bands, which are quite as flexible as any of the foregoing.

The only disadvantage of the band conveyor is that while it can be fed at any number of points by making adequate provision, the withdrawal of the material *en route* is somewhat complicated. It is true that, with an oblique plough, material can be scraped off at intermediate points if the band speed is low, but even then it is a makeshift and shortens the life of any but a steel band, for which such ploughs are therefore ordinary standard practice. For all textile and textile-rubber bands what is known as a "throw-off" or tripper gear is necessary. Such a throw-off device is shown diagrammatically in fig. 5. The full lines denote the machine in action, the band passing over idlers A^1 and B^1; as shown in dotted lines, idlers A and B are out of action when the band with its load passes by.

The Shuttle Conveyor is an important application of the band conveyor. Its use can best be visualized by an example. For

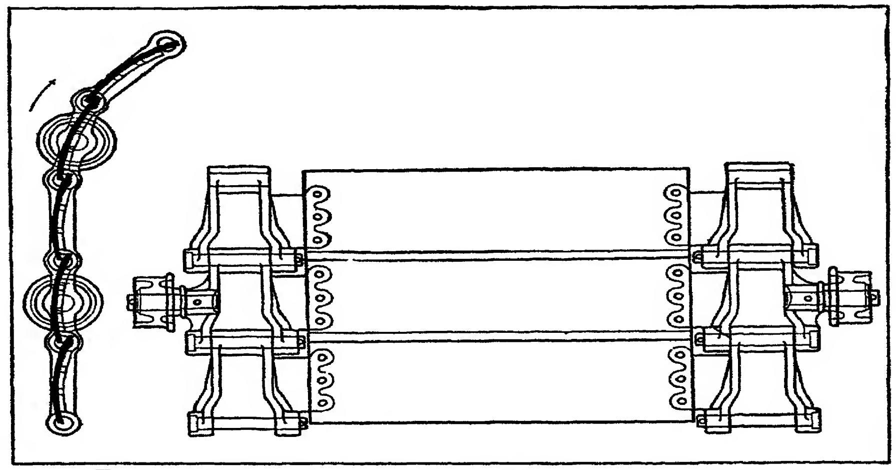
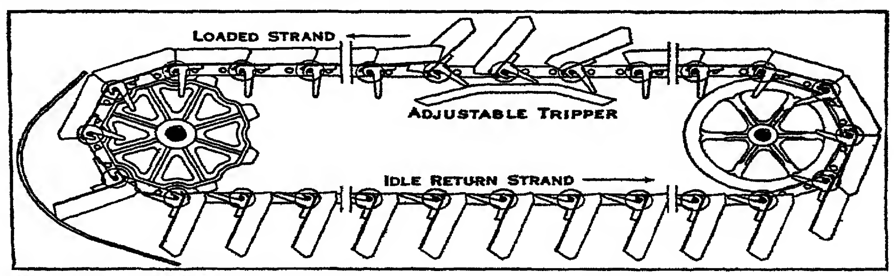


FIG. 6.—PORTION OF APRON CONVEYOR WITH STEEL SLATS

instance, in a very long boiler house, where it is essential that the coal be delivered in a central position, an elevator or a skip hoist is installed to lift the coal to a level above the bunkers. Instead of providing two band conveyors, one on the right and the other on the left, for distributing purposes, only one length is installed, reaching from the elevator or skip hoist to the bunker most remote from the central position. This is mounted on rails and is made reversible so that it can be run either to the right or to the left.

With regard to the speed at which band conveyors may run this may be said, broadly, to be 600 ft. per minute when handling maize, etc., while when handling lump coal it should not be more than 150 to 250 ft. per minute.

Articulated Band Conveyors.—A number of conveyors are in use on the same principle as the band conveyor, but where endless chains replace the band and to which are attached a variety of carrying elements. These may be likened to, and in fact are, articulated band conveyors. These all run at relatively slow speeds. The type most frequently used is the slat or apron conveyor. It has the usual two sprocket terminals. Every link or every other link of the chains is provided with slats of iron, or of wood, furnished at their ends with small supporting rollers. (*See* fig. 6.)



BY COURTESY OF BABCOCK & WILCOX

FIG. 7.—DIAGRAM SHOWING MAIN FEATURES OF TIPPING-TRAY CONVEYOR

For handling small coal, etc., conveyors with steel slats, bent up at the sides, are employed. They are called continuous trough conveyors and form articulated troughs. A modification is introduced for the purpose of effecting intermittent delivery. It is known as the *Tipping-Tray Conveyor* and is illustrated in fig. 7.

Reciprocating Conveyors.—(*See* fig. 8.) These are essentially steel troughs which are set into frequent reciprocating motion, so that with the forward stroke the material travels with the trough, while the trough returns to its initial position without the material, which travels forward in an almost continuous stream.

Coal Face Conveyors.—All the foregoing types are employed in collieries, but their construction is somewhat different on account of the confined head-room in the coal seams. They are generally from 100 to 180 yd long to reach from gate to gate, and are so built that they can be readily taken down as the coal face recedes and be re-erected elsewhere.

When inclines have to be negotiated in favour of the load, what is known as a *retarding conveyor* is employed similar in principle to that last described, but with wire ropes instead of chains to which cast-iron discs are clamped at regular intervals.

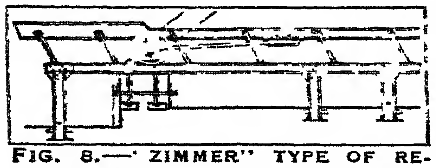


FIG. 8.—"ZIMMER" TYPE OF RECIPROCATING TROUGH CONVEYOR

Such devices need no driving power, but rather a brake, if the incline is steep enough.

All types of chain conveyors so far discussed employ endless chains running on vertical sprockets, so that the two strands are disposed one above the other. In another type, known as general purpose conveyors the chains run over horizontal sprockets, so that the two strands are side by side, or by the addition of guide idlers they may run over a more complex path on an essentially horizontal plane.

Gravity Roller Conveyors.—Gravity roller conveyors consist of benches, the upper surface of which is provided with light rollers of two to three inches in diameter, placed close together

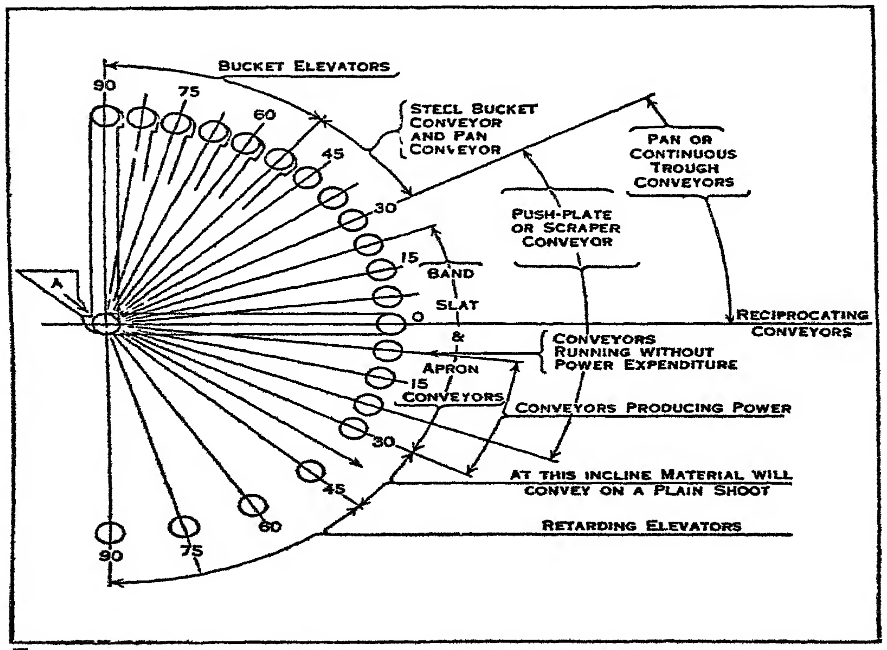


FIG. 9.—DIAGRAM SHOWING THE INCLINES AT WHICH VARIOUS TYPES OF CONTINUOUS CONVEYORS ARE APPLICABLE

and running in ball bearings disposed at a downward gradient of 2% to 5%, so that any object with a flat base, such as a packing case, can run down by gravity.

A great variety of types of continuous handling machinery are employed in modern factories. Sometimes when conveying material from one point to another it is exceedingly difficult to determine which of the many devices obtainable is best suited for the specific purpose in hand. The accompanying diagram, fig. 9, will be helpful in such a case. On the left hand side it shows a hopper A, containing a material which will run down an incline of 45°, and which will therefore convey itself by gravity to any one of the conveying devices represented by radial lines in the diagram. The circles to the left of the datum line represent the receiving terminals of all types of conveyors or elevators. The devices shown by circles in a variety of positions may be what are usually known as bucket elevators, bucket conveyors, etc., according to the incline at which they work. At an angle of 90° to the datum line, and above, such a device would be a bucket elevator, and would remain so at any angle to about 67·5°, when it would merge, stage by stage, into a bucket, tray, push-plate, slat, apron or band conveyor, the latter on the datum line.

All devices above the datum line must, obviously, be power-driven, the actual power expenditure depending upon the height to which the material has to be raised, plus power necessary to overcome friction. If it be assumed that all the devices shown on the diagram are of the same capacity, *i.e.*, carry the same load in a unit of time, the driving power needed will decrease gradually until the conveyor parallel with the datum line is reached, where only frictional resistance has to be overcome. Below the datum line gravity enters into the calculation, so that at a downward gradient of about 7½° gravity alone is sufficient to overcome frictional resistance and the conveyor will run by itself. Finally, there are positions which would need a retarding conveyor or inverse elevator. As the down gradient increases, gravity assists further, *pro rata*, and if suitable gear is applied to one of the conveyor terminals energy may be collected to actuate other machines, to be converted into heat by a brake, or to be dissipated.

The usual type of conveyor for moving material both horizontally and vertically is known as the bucket conveyor. It resembles the bucket elevator very closely, but the buckets are rather different.

Another type is the V-bucket conveyor, the buckets of which are V-shaped and attached to two endless chains, one at each side. The portion of such a conveyor which runs horizontally, constitutes a scraper conveyor, and that which runs vertically, a bucket elevator. At the junction of the horizontal and vertical runs the material drops automatically into the buckets. The path of the conveyor may be L-shaped or in the form of an oblong, but the machine must always discharge on a horizontal run if ever so short.

If the buckets are not rigidly connected to the chains but supported on trunnions and above their centre of gravity they constitute what is known as the *gravity bucket conveyor*. Devices of this kind are generally so disposed in power-houses that the lower horizontal run passes along the basement floor, ascends at one end of the building, traverses the top floor above the bunkers and descends at the other end, thus forming an oblong. Owing to their method of suspension the buckets always remain in a perpendicular position, except when they are tipped and thus emptied by coming in contact with a tripping device at the various points of discharge. They are filled in the basement by a rather complex feeding device while the chain of buckets is under way. Gravity bucket conveyors were at one time largely used in power-houses, where they sometimes handled coal on the ascending and upper horizontal run, discharging the coal into the bunkers, while the lower run collected the ashes. They are slow-running, rather expensive machines, but very reliable. As, however, they are now but rarely installed, no further comment is necessary. Pneumatic handling is dealt with in a separate article. (*See* PNEUMATIC CONVEYING.)

Intermittent Handling Devices.—The following types are the most important under this heading: ropeways and aerial cableways; mono-rails and telphers; finger-tray elevators; and skip hoists. The last two devices only are dealt with here, the others form the subjects of separate articles.

Finger- or Swing-Tray Elevator.—This device serves the same purpose as a bucket elevator, but handles larger intermittent loads such as packages, cases, baskets, sacks, barrels, etc. It can receive goods on any one floor and set them down on any other. The loads are picked up on the ascending strand and set down on the descending one. The device consists of one or two endless chains with corresponding upper and lower sprocket terminals.

The Skip Hoist.—This device may be likened to a bucket elevator having only one bucket, which, instead of running continuously in the same direction as the former, works intermittently up and down a vertical or steeply inclined rail-track. With a twin installation one skip is in the loading position while the other is discharging; usually the discharge is over the top, like a "monkey-on-a-stick."

The size of the skip is determined by the tonnage to be handled

and the depth of the pit. The skip may be of either the top or bottom discharge type. In the former instance the skip is provided with a bail, to the base of which it is hinged. At its upper end are trod wheels, which follow at the discharge point along an approximately horizontal path, whereby the skip is tipped and emptied. As a rule there are also a pair of trod wheels which guide the lower end. With bottom-discharge skips, as the name implies, a door is provided at the base of the skip, which at the same time forms a shoot, and which is kept closed during travel, generally by means of a pair of wheels which engage in a certain way. At the discharging point these rails are interrupted, when the weight of the contents forces open the door and thereby effects discharge.

In operation the initial speed of travel of a skip hoist is slow, increasing to a maximum of 5 ft. per sec.; decreasing when approaching upper delivery point. The speed may be controlled by the form of the drum on which the wire rope is wound, this being lemon-shaped; or in large installations by automatic speed variation of the motor. Skip hoists are in use for twin installations, with maximum handling capacity of 500 tons per hour and skips holding 6 cu. yds. (*See* MASS PRODUCTION)

See H H. Broughton, *Electrical Handling of Materials* (1921–23); H V. Hetzel, *Belt Conveyors and Belt Elevators* (1922, 2nd ed., 1926); G F. Zimmer, *Mechanical Handling and Storing of Material* (1916, 3rd ed., 1922). (G F. Z.)

MECHANICAL IMPROVEMENT: *see* POWER TRANSMISSION.

MECHANICAL MAN: *see* ROBOT; AUTOMATIC MACHINES.

MECHANICAL REFRIGERATION: *see* REFRIGERATION AND ICE MANUFACTURE.

MECHANICS. This branch of applied mathematics deals with the motions of bodies; with the forces by which those motions are conditioned, and with the balance of forces on a body at rest. The word implies a connection with machinery (Gr. μηχάνη); but this and other practical applications are to-day more commonly included under the heading of "applied mechanics," which covers such subjects as elasticity and the strength of materials, hydromechanics and aerodynamics, mechanism, ballistics, etc. (*qq.v.*).

Theoretical mechanics, the foundation of all these subjects, may be divided into two closely related parts: *dynamics,* which is concerned with moving bodies, and *statics,* which treats of equilibrium, or rest. Dynamics—so-called because one aspect of the interaction between bodies, by which their motions are conditioned, is the occurrence of what we recognize as *force* (Gr. δύναμις)—may again be subdivided into *kinematics,* which deals with motion from the standpoint of measurement and precise description, and dynamics proper, which is concerned with causes, or "laws" of motion. Statics, the theory of balanced forces, can be established on foundations of its own, as an independent science; but it is now customary to base it on the laws of dynamics, of which science it thus becomes a special branch. This procedure will be followed in this article, which attempts to present the essential features of the Newtonian scheme.

Speaking broadly, two standpoints are possible. The first presents dynamics as a science which has been constructed, by induction, on a basis of experiment. Corresponding with the axioms of Euclidean geometry (which "neither require, nor are capable of proof") we have, in dynamics, "laws of motion," *e.g.,* a body which is not disturbed by force continues to move with uniform speed in a straight line. These "laws," it is claimed, can be put to the test of experiment; and on them, step by step (as in the successive propositions of Euclid), is developed a system not only embracing in its scope all motions which occur in the material universe, but which has been proved by actual trial to maintain contact with that universe at every stage.

Difficulties in Verification of Laws.—It is recognized, of course, that practical limitations prevent an exact verification of any theoretical "law"; but a far more serious objection can be advanced against this presentation of dynamics, in that it involves an "argument in a circle": with whatever refinement the experiment is made, it cannot be interpreted without recourse to ideas which are themselves an essential part of the theory under examination. For example, if we seek to verify the "law" which has been stated above, our first requirement is a body free from the action of force; but no such body is available for test, because any body to which we can have access is subject to the earth's attraction. Therefore we must arrange that the attraction, since it cannot be eliminated, shall be neutralized, and this is attempted in what is known as "Attwood's machine": the body under test is connected, by a light string passing over a freely-running pulley, with a second body of equal weight; and under these conditions it is found that, started with any initial velocity, it retains that velocity almost unchanged. However quite apart from the fact that a small reduction in velocity (which may reasonably be attributed to friction) is always observed in any actual experiment, there are difficulties in accepting this result as a proof of the "law" in question. We have found that a body moves with (substantially) uniform speed and direction; but it is *not* a body on which no force is acting, and without recourse to the principles of dynamics (themselves dependent on the law) we have no grounds for asserting that the forces which act upon it do in fact neutralize one another.

Dynamics as an Abstract Science.—Difficulties of this kind are avoided if we adopt the alternative standpoint, according to which dynamics, as a purely abstract science, may legitimately be founded upon any set of initial assumptions (or "laws of motion") which is convenient and not self-contradictory. In constructing this theoretical system, we are under no obligation to verify that contact with the actual universe is maintained at every stage; for the system is concerned with the motions of purely ideal bodies whose properties are postulated in its fundamental assumptions, and provided that it is developed by logical processes, according with the accepted principles of mathematics, its conclusions will be valid consequences of those assumptions Whether it will lead to results having any correspondence with the observed motions of actual bodies is an entirely separate question, which must be decided *a posteriori,* by comparing these results with experiment. But the available tests apply only to the system as a whole: we cannot devise an experiment which will verify any one of its assumptions apart from the rest.

It follows that any special importance which these assumptions may have, in relation to the actual universe, arises solely from the fact that they constitute the simplest possible description. To describe the motions of the bodies which form our solar system. we may either, as in the Ptolemaic system, specify the motions of those bodies relative to the earth, or, as in the Copernican system, specify their motions relative to the sun. Either description (provided that its details are correct) is equally valid, and the superior merit of the Copernican system consists solely in the fact that its description is simpler. It remained for Newton to discover a still more simple description, by inventing a comprehensive theory of dynamics which follows logically from three fundamental assumptions, or "laws." However his theory is still description, it does not explain; for whilst, like the axioms of geometry, his laws are incapable of proof, they cannot by any stretch of imagination be regarded as self-evident and therefore needing no proof.

Newton's assumptions are incapable of proof, *i.e.,* of direct verification by experiment, for reasons which have been indicated already; but, from the standpoint now considered, such verification is in no way essential to the development of his theoretical system, and the appeal to experiment, by which that system is related with the actual universe, can equally well be made when the system is complete. Whatever view be taken of the philosophical question, it must be admitted that the real evidence for his "laws," as an expression of the facts of nature, is to be found, not in laboratory experiments aimed at direct verification, but in the close accord with experience of every conclusion which has been based upon them.

KINEMATICS

Speed.—1. The notion of *speed, e.g.,* of a car or railway train, is familiar in every-day experience. When we say that a train is travelling with a speed of 60 miles per hour, we mean that it is moving at a rate which, maintained constant, would take it 60 miles along its route in one hour, one mile in every minute, or 88

feet in every second. We do not mean that this rate is in fact constant: a train which is travelling at 60 miles per hour may, during the next few minutes, increase its speed, stop, or ever retrace its path. What we mean is that the actual distance travelled will be 88 ft., very nearly, in the next second, 8·8 ft., almost exactly, in the next tenth of a second, and so on: given the instantaneous value of the speed, we can foretell the distance more closely, the shorter the interval of time.

Kinematics gives precision to this idea of speed by fixing attention on an interval which is indefinitely short. Let s be the distance of the train from its starting point, t the time which has elapsed since the start; then, as the train moves s will increase with t. If the speed is constant from the start (say S miles per hour), and if s is measured in miles and t in hours, then evidently s and t will be connected by the relation

$$s=St. \qquad (1)$$

and in a further interval of t' hours the increase in s will be s' miles, where

$$s'=St'. \qquad (2)$$

When the speed s is variable, (1) will no longer hold; but the relation (2) will still be satisfied, provided that t' (and therefore s') is indefinitely small. On this understanding we have

$$S=\frac{s'}{t'};$$

i.e., in the notation of the calculus,

$$S=\frac{ds}{dt}; \qquad (3)$$

so the speed S may be found by *differentiating* the distance s with respect to the time t.

2 Almost all cars, and occasionally trains, carry an instrument which records the distance travelled. If we take simultaneous readings of this instrument and of a clock, we can plot, in accordance with the principles of graphical representation, points which relate corresponding values of s and t; and if a large number of such points are plotted and connected by a continuous curve, this curve may be taken to represent the relation between s and t over the whole period of the observations. A curve of this nature is called a distance-time or s-t diagram: if P (fig. 1) is a point on the curve, we know that the car or train was, at a time represented (on the time-scale) by the length OL, at a distance from the starting-point, which is represented (on the distance scale) by the length OH.

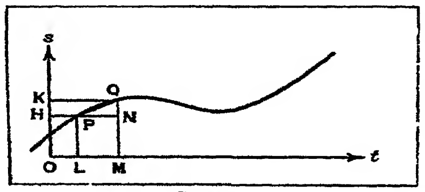


Fig. 1

Now let Q be another point on the curve. Then we know that the distance from the starting-point, at a time represented by the length OM, is the distance represented by the length OK; and it follows that a distance represented by the length HK was travelled in an interval of time represented by the length LM. This means that the average speed during that interval of time is given by

$$\frac{\text{distance represented by } HK, \text{ or } QN}{\text{time represented by } LM, \text{ or } PN};$$

i.e., it is measured by the *slope* of the line PQ.

Speed Represented by Slope of Tangent.—If the speed were in fact constant, this slope would be constant for all intervals of time; so we see that the s-t diagram for motion at constant speed is a straight line. In general the speed will vary during the interval considered; but its variation may be neglected if the interval be sufficiently small; *i.e.*, if Q be sufficiently near to P. Ultimately, when the interval is infinitesimal, PQ is the tangent at P. We thus obtain a graphical interpretation of the formula (3): in a distance-time diagram, the speed at a time corresponding to P is measured (on an appropriate scale) by the slope of the tangent at P. Even when the formula (3) cannot be used, because s is not known as a mathematical function of t, the speed can be estimated by graphical methods.

Distance Represented by Area Under Curve.—3. Mathematically the formula (3) implies that

$$s=\int S dt; \qquad (4)$$

i.e., the distance s may be found by *integrating* the speed S with respect to time t. Let S and t be related, after the manner of fig. 1, in a speed-time diagram (fig. 2): the graphical interpretation of (4) is that the area under the portion PQ of the speed-time diagram measures (on an appropriate scale) the distance travelled in the interval represented by LM.

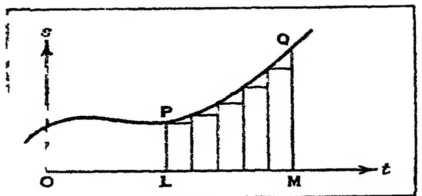


Fig. 2

To establish this rule independently, we have only to notice, (1) that it would be obviously true if the speed were uniform—in which case PQ would be a horizontal straight line, and the area would be proportional to (speed) × (length of interval); (2) that it would be true if the speed changed suddenly at the ends of finite but short intervals, and remained constant during those intervals, so that the speed-time curve consisted of a number of small steps, as indicated in fig. 2; and (3) that the conditions contemplated in (2) will be indistinguishable from the actual conditions, and the stepped diagram indistinguishable from the actual curve, if the intervals are sufficiently short.

Acceleration.—4 When the speed varies, we use the term acceleration to denote the rate at which it increases. Thus, if the speed of a train changes from 6 to 10 ft. per second in an interval of 2 seconds, the total increase in speed during this interval is $10-6=4$ ft. per second, and hence the average rate of increase, *i.e.*, the average acceleration of the train, is $\frac{4}{2}=2$ ft. per second per second. In symbols, if the speed increases by S' in an interval of time t', then the average acceleration is measured by

$$\frac{S'}{t'}.$$

To obtain an accurate measure of varying acceleration, we make the time interval t', as before, indefinitely small. Corresponding to (3) we have, as an expression for the instantaneous acceleration f,

$$f=\frac{dS}{dt}, \qquad (5)$$

and corresponding to (4) we have

$$S=\int f\, dt. \qquad (6)$$

Thus the acceleration f may be found by differentiating the speed S, and the speed by integrating the acceleration, with respect to the time t. Similarly, in relation to graphical methods, we may say that:

(a) in a speed-time diagram, the acceleration corresponding to a point P is measured (on an appropriate scale) by the slope of the tangent at P;

(b) The area under a portion PQ of the acceleration-time diagram measures (on an appropriate scale) the increase of speed in the corresponding interval of time.

Velocity.—5. In this discussion of speed and acceleration, we have not been concerned to know the route of our train. Distance (s) has meant distance measured, from some arbitrary starting point, along the route; and in this sense a train can be said to be distant s from the starting point, although it may be, if the route is circuitous, much nearer "as the crow flies" Speed and acceleration have been understood, similarly, as measured along the route. Direction has had no meaning, except in the sense that the train may be travelling forwards or back, *i.e.*, with positive or negative speed

These ideas were sufficient, because we were concerned with motion in some definite path, or route If, instead of the train, our concern had been with a ship, we should have had to consider the direction, as well as the speed, of its motion at every instant.

Whereas the position of the train could be specified by means of one quantity (the distance s), two quantities are required to fix the position of the ship: thus, if O (fig. 3) is a fixed point on the earth's surface, and ON, OE are lines through O in a northerly and easterly direction, the position P can be specified by assigning values to the distances PK, PL.

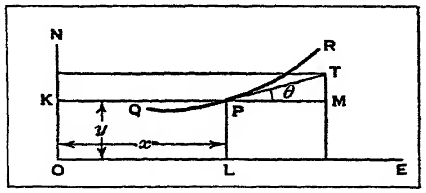


FIG. 3

Let QPR be the path of the ship. Then, as the ship moves from P in the direction of R, the distances PK, PL, *i.e.*, the lengths OL and OK, will increase. Let x and y (according to the usual convention) denote these distances, or coordinates. Then the speed u with which the ship is travelling east will be the rate at which x increases; *i.e.*, we shall have, as in equation (3)

$$u = \frac{dx}{dt}. \tag{7}$$

Similarly, the speed v with which the ship is travelling north will be given by

$$v = \frac{dy}{dt}. \tag{8}$$

The actual direction of motion, when the ship is at P, is along the tangent at P to the path QPR; the speed along the path has, at this instant, some definite value S. We say that the ship has a *velocity* S in the direction of the tangent. Thus velocity is a quantity which has the nature of a speed, but which also possesses direction; in equations (7) and (8), we may say that u is the eastward and v the northward velocity of the ship.

Composition and Resolution of Velocities.—6. We have seen that the actual velocity S of the ship at P may be regarded as a combination of the two velocities u and v: when u and v are both known, it must evidently be determinate, both in magnitude and direction. To find the required relations between S, u and v, we have only to imagine that the ship, on reaching P, maintains its velocity unchanged. The path then becomes a straight line PT (fig. 3), and in an interval t the ship will go to T, where

$$PT = St, \tag{9}$$

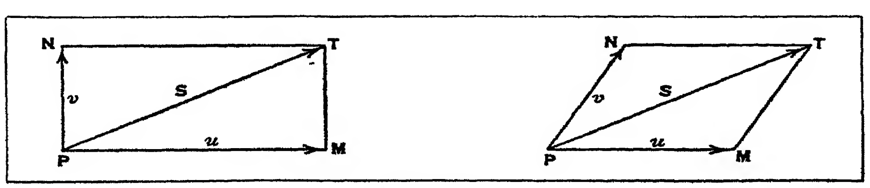
as in (1). Also, since u is the eastward velocity, and LH (or PM) the eastward distance covered in the interval t, we have

$$PM = ut; \tag{10}$$

hence, dividing corresponding sides of (9) and (10), we deduce that

$$\left.\begin{aligned} \frac{u}{S} &= \frac{PM}{PT} = \cos\theta, \\ \text{and similarly,} \quad \frac{v}{S} &= \frac{MT}{PT} = \sin\theta. \end{aligned}\right\} \tag{11}$$

The Parallelogram Law.—Thus (fig. 4) the component velocities u, v and the resultant or total velocity S can be represented both



FIGS. 4–5

in direction and magnitude by the sides and diagonal, respectively, of a parallelogram. In this particular instance the parallelogram is a rectangle; but the same result can be established when (as in fig. 5) the directions of u and v (*i.e.*, the directions of the coordinates x and y) are not perpendicular. The total velocity S may be regarded as made up of two velocities, u, v, represented in direction and magnitude by PM and PN, the sides of any parallelogram of which PT is a diagonal.

Composition and Resolution of Accelerations.—7. Similar relations hold for accelerations; *i.e.*, a resultant or total acceleration F may be resolved into two components (*e.g.*, an eastward acceleration f_x combined with a northward acceleration f_y) which are related with F by the parallelogram law. Corresponding to equation (5), we shall have

$$\left.\begin{aligned} f_x &= \frac{du}{dt}, \\ &= \frac{d^2x}{dt^2}, \text{ by (7)}, \\ \text{and} \quad f_y &= \frac{dv}{dt}, \\ &= \frac{d^2y}{dt^2}, \text{ by (8)}. \end{aligned}\right\} \tag{12}$$

KINEMATICS OF THREE DIMENSIONS

The Vector Law.—8. Two coordinates x, y suffice to define the position of a ship, because this is (practically speaking) a body moving in one plane. To define the position of an aeroplane, we require a third coordinate; viz., the height z above some standard level. Corresponding to (7) and (8), we have the expression

$$w = \frac{dz}{dt}, \tag{13}$$

for the vertical component of velocity; and corresponding to (12) the expression

$$f_z = \frac{dw}{dt} = \frac{d^2z}{dt^2}, \tag{14}$$

for the vertical component of acceleration.

The parallelogram law has an obvious extension in three dimensions. If OP, the diagonal of a parallelopiped (fig. 6), represents a velocity or acceleration in direction and magnitude, this may be resolved into components represented in direction and magnitude by OA, OB, OC, the sides of the parallelopiped. Speaking generally, we say that velocities and accelerations may be resolved and compounded according to the vector law.

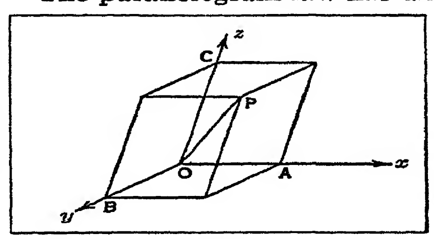


FIG. 6

Motion of a Projectile in Vacuo.—9. A simple example will serve to explain the application of these kinematical principles. We may assume (as a deduction from experiment) that a body moving *in vacuo* near the surface of the earth has a constant total acceleration g directed vertically downwards: making this assumption, we proceed to calculate its path, or *trajectory*.

To define the position of the moving body (or *projectile*), we take axes Ox, Oy, Oz, fixed in relation to the earth. We take Oz to be directed vertically upwards; *i.e.*, in the line of the resultant acceleration. Then the acceleration has no component along Ox or Oy, and we have from (12) and (14),

$$\left.\begin{aligned} \frac{du}{dt} &= f_x = 0, \text{ whence } u = \text{const.}, \\ \frac{dv}{dt} &= f_y = 0, \text{ whence } v = \text{const.}, \\ \frac{dw}{dt} &= f_z = -g, \text{ whence } w = (\text{const.}) - gt. \end{aligned}\right\} \tag{15}$$

Now let Oy be taken horizontal and perpendicular, at some definite instant ($t=0$), to the direction of motion; then, at this instant, there is no component velocity in the direction Oy; *i.e.*, $v=0$. Hence, according to the second of equations (15), v will be zero always; *i.e.*, the trajectory lies wholly in the plane zOx.

The problem is now two-dimensional. If u_0, w_0 are the initial components of velocity (viz., at time $t=0$), we have from (7) and (15),

$$\frac{dx}{dt}=u_0, \text{ whence } x=u_0t+\text{const.},$$
$$\text{and} \quad \frac{dz}{dt}=w_0-gt, \text{ whence } z=w_0t-\tfrac{1}{2}gt^2+\text{const.} \quad (16)$$

Finally, let O (fig. 7) be the position of the particle at the instant ($t=0$). Then the constants in (16) will vanish, and we may write

$$t=x/u_0,$$
$$z=w_0t-\tfrac{1}{2}gt^2=\frac{w_0}{u_0}x-\frac{1}{2}\frac{g}{u_0^2}x^2. \quad (17)$$

The form of this relation between z and x shows that the path is a parabola. z vanishes when $x=0$ (*i.e.*, at the point O), and again when

$$x=\frac{2u_0w_0}{g}=R. \quad (18)$$

10. Equation (18) gives the *range* OP of a projectile, on any inclined plane Ox, in terms of the circumstances of projection. If OT be the tangent to the trajectory at O, and if OT represents the velocity at this point, then ON, OM (fig. 7) will represent u_0 and w_0, according to the parallelogram law. Hence we see that

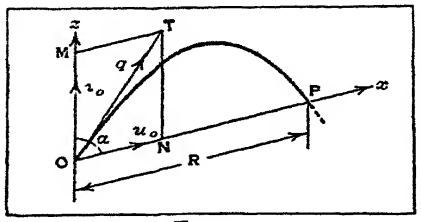


FIG. 7

$$\begin{aligned} q^2&=u_0^2+w_0^2+2u_0w_0\cos\alpha,\\ &=(u_0-w_0)^2+2u_0w_0(\cos\alpha+1), \quad (19)\\ &=(u_0-w_0)^2+gR(\cos\alpha+1), \end{aligned}$$

by (18), where R is the range. Clearly, if q and α are fixed, R will be greatest when $u_0=w_0$; *i.e.*, when OT, the direction of projection, is equally inclined to Ox and Oz. The maximum range for the plane Ox is

$$R_{max}=\frac{q^2}{g(1+\cos\alpha)}, \quad (20)$$

and all points on Ox whose distance from O is less than R_{max} will be within range of a projectile started with velocity q.

11. Now suppose that q is fixed but α varied; then we have a different value of the maximum range for every slope. Writing r for R_{max}, the value corresponding to α, we have from (20)

$$\frac{l}{r}=1+\cos\alpha, \text{ where } l=\frac{q^2}{g} \quad (21)$$

Equation (21) holds of all points which are just within range of O, for a projectile started with velocity q: its form shows that such points lie on a parabola (APQ, fig. 8), having its focus at O and vertex at A, where $OA=q^2/2g$. The (parabolic) trajectory which goes through P is shown by a dotted line; its original direction OT bisects the angles AOP, and it touches the parabola APQ. Every direction of projection gives a maximum range for some plane; hence the parabola APQ will be touched at some point by every trajectory having initial velocity q, and all points inside it are within range of O. It is called the "parabola of safety." (*See* also the special article on KINEMATICS.)

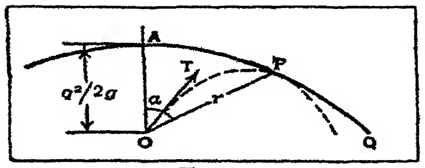


FIG. 8

DYNAMICS

12. The general problem of dynamics is to investigate the motions of two or more bodies, as affected by interaction. Such interaction may be caused by collision, as of two billiard balls, or it may be due to mutual attraction, as of the earth and the sun. Following Newton, we shall describe it as operating by the exertion of *force*; when two bodies A and B interact, we say that A exerts a force on B, and that B exerts a force on A. From a strictly logical standpoint the notion of force is unnecessary; but it is convenient, since it enables us (in theory) to confine attention to a single body. Thus, in the problem just discussed, we are really concerned with the relative motion of two bodies, the projectile and the earth; but we can confine attention to the projectile, once we have postulated that its interaction with the earth is equivalent, so far as its own motion is concerned, to the imposition of a force which gives it a constant downward acceleration g.

The "Laws of Motion."—13. Newton's "laws of motion" are postulated relations between forces and their effects. If we were concerned merely to formulate an abstract scheme of dynamics, having no necessary relation to the material universe, we could postulate any relations that are self-consistent. Newton was concerned to "explain" (*i.e.*, to describe) the observed motions of the heavenly bodies, and the special significance of his relations lies in the fact that they lead to deductions which are confirmed by experiment. This fact, however, does not compel us to appeal to direct experiment for a justification of his "laws": as stated already, we are quite at liberty to postulate them arbitrarily, as fundamental axioms of an abstract dynamical scheme, and to leave for subsequent investigation the question whether this scheme does in fact correspond with "reality."

Newton's First Law.—14. The first question which presents itself is, what is the behaviour of a body which is not affected by force? Newton's answer to this question is contained in his first law: "Every body remains in a state of rest or of uniform motion in a straight line, unless it is compelled by impressed forces to change that state." This law, sometimes called the "law of inertia," had been propounded by Galileo in 1638, nearly fifty years before the appearance of Newton's *Principia*.

To give precision to the foregoing statement, we must explain what we mean by "a state of rest." The position of a body in space can be defined (§ 8) by specifying the values of three coordinates x, y, z, relative to axes Ox, Oy, Oz. When x, y and z have constant values (not varying with time), we may say that the body is at rest in relation to Ox, Oy, Oz; if these axes are moving in space, the body will move with them: if they are fixed in space, the body may be said to be in a state of absolute rest. The difficulty in this description (if we keep in mind the question of an ultimate appeal to experiment) is to state what we mean by "axes fixed in space." From a logical standpoint, this is a serious difficulty in the Newtonian scheme. For practical purposes however we may be content with the assertion, that we are at liberty to postulate the existence of *some* fixed system of axes, when we formulate our abstract scheme of dynamics; and that we shall be involved in no sensible error, when we come to a comparison with the real universe, if we assume that these axes are at rest in relation to the "fixed" stars. By "uniform motion in a straight line" Newton means, in our language, "velocity constant in magnitude and direction." So the answer to our first question is definite: the motion of a body not affected by force may be described, in accordance with the kinematical principles of §§ 5–8, as a motion, referred to a system of axes fixed in space, in which the component velocities u, v, w do not vary with time.

Newton's Second Law.—15. It follows from this discussion that, if u, v, w vary with time (*i.e.*, if the body has acceleration in relation to the fixed axes), then forces must be assumed to act. The next question is, how do forces affect the motion of a body?

Newton's second law states: "Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which that force is impressed." "Change of motion," in our language, may be taken to mean *acceleration*: we deduce that the possession by a given body of an acceleration F in any direction implies that a force P, proportional to F, must be acting in that direction; *i.e.*,

$$P=MF, \quad (22)$$

where M has some constant value.

16. Let F be equivalent to (or the *resultant* of) three component accelerations f_x, f_y, f_z in the directions of the fixed axes Ox, Oy, Oz. Then the possession by the given body of an acceleration f_x alone would imply the existence of a force X, parallel to Ox and

of magnitude

$$X = Mf_x;$$

similarly, its possession of accelerations f_y and f_z, alone, would imply the existence of forces Y and Z respectively, where

$$Y = Mf_y,$$
$$Z = Mf_z.$$

We postulate that two or more forces acting simultaneously produce an acceleration which is a combination (*i.e.*, the resultant) of the accelerations which they would produce when acting separately; and since F is the resultant of the accelerations f_x, f_y, f_z, we deduce that the forces X, Y and Z, acting together, produce the same effect as the single force P. So P may be regarded as the resultant of three component forces X, Y, Z; and since these four forces are proportional to the accelerations F, f_x, f_y, f_z, it follows that forces, like accelerations, can be resolved or compounded by the vector law.

Inertia.—17. This last result will be made the basis of the science of *statics* (§ 37). If now we imagine the body to be changed, it is clear that, whilst Newton's second law will still hold, the constant of proportionality M in equation (22) may be different. We must regard M as a quantity associated with a given body: it is termed *inertia* (*i.e.*, sluggishness), because, according to equation (22), the acceleration produced by a given force will be less, the greater the value of M. Inertia, regarded as a measurable quantity, is commonly designated by the term *mass*, and defined as the quantity of matter in the body.

When the mass of a body is specified, and the magnitude and direction of the force which acts upon it, the acceleration F can be deduced, and we are left with a problem in kinematics; *e.g.*, if we know that the earth exerts on any body a constant downward force, we may conclude that it gives to the body a constant downward acceleration, denoted by the symbol g; so the problem of a projectile in vacuo may be treated as an example in kinematics (§§ 9–11).

Newton's "Third Law."—18. As we have stated above, force is to be regarded merely as one aspect of a mutual action between two bodies. If a body A experiences a force P in consequence of interaction with another body B, then B will also be subjected to force. This principle is propounded in Newton's third law of motion: "Action and reaction are equal and opposite;" *i.e.*, we postulate that the force experienced by B will be a force equal in magnitude but opposite in direction to the force P, and having the same line of action.

On the basis of these three laws, with a further postulate regarding the mutual attraction of two bodies at a distance (*i.e.*, the "law of gravitation"), Newton erected the whole structure of his dynamical scheme. That structure, as we have already inferred, is purely mathematical, concerned to work out, according to the laws of kinematics, the consequences of accelerations which are postulated in the so-called "laws of motion." Force and mass are secondary notions, not really essential to the scheme, but they simplify its presentation, and for this reason it is convenient to retain them, and even to introduce further dynamical concepts which may be based upon the fundamental relation (22). These concepts we now proceed to develop. We shall show that the laws of motion, applied to a single mass, lead to relations which hold in respect of any system of masses, and form the basis of general equations (*see* DYNAMICS).

Units of Measurement.—19. Before we can employ equation (22) to deduce exact numerical results, we must define the units in which force, mass and acceleration are to be measured. The unit of acceleration will be that which involves a unit increase of velocity in a unit of time; and the unit of velocity will be the velocity of a point which moves through a unit of distance in a unit of time. Thus, in the first place, we have to fix the fundamental units of length and time: if, for example, we choose the foot and the second, the unit of velocity will be 1 ft. per sec. and the unit of acceleration will be 1 ft. per sec. per sec. Inertia being defined (§ 17) as a constant quantity associated with a given body, independent of its velocity or acceleration, the unit of mass will be another fundamental (and therefore arbitrary) unit. It must be defined as the mass of some particular piece of matter; *e.g.*, the standard pound or kilogram.

When we have specified the fundamental units of length, mass and time, we may deduce, according to (22), the corresponding unit of force. If, for example, we adopt the "C.G.S. system," in which the fundamental units are the centimetre, gram and second, the unit force will be that force which produces an acceleration of 1 cm. per sec. per sec. when it acts on a mass of 1 gram: this unit is termed the *dyne*. If we adopt as units the foot, pound and second, the unit force will be that which produces an acceleration of 1 ft. per sec. per sec. when it acts on a mass of 1 pound: this unit is termed the *poundal*.

A unit of force derived in this way from (22) is termed an *absolute unit*, since it is the same in all places and at all times. Now consider the case of a body of unit mass falling freely under the influence of the earth's attraction. In (22) if g is the measured acceleration, we have

$$M = 1,\ F = g;$$

hence the attractive force, *i.e.*, the "weight" of the body, consists of g absolute units. Measured in centimetres per second per second, g is 981, nearly; so the weight of 1 gram is a force of 981 dynes, and conversely, the unit of force in the C.G.S. system (*i.e.*, 1 dyne) is about $\frac{1}{981}$ of a gram weight. Measured in feet per second per second, g is 32·2 nearly; so the weight of 1 pound is a force of 32·2 poundals, and conversely, the poundal is a force of about $\frac{1}{32\cdot2}$ lb. weight, *i.e.*, roughly equal to the weight of half an ounce.

For scientific purposes, great advantages are possessed by an *absolute* system of measurement, and the C.G.S. system is now almost universally employed (*see* UNITS, PHYSICAL), but in practical applications of mechanics (*e.g.*, engineering) it is customary to take as the unit of force the weight of one pound; *i.e.*, a force of g poundals. This change of units will evidently involve a change in the form of (22). A force which in poundals is measured by MF will be measured in pounds weight by MF/g, where $g = 32{\cdot}2$ approximately: hence we have the expression

$$P = \frac{MF}{g} \qquad (23)$$

for the accelerating force measured in pounds weight, when M, the mass accelerated, is measured in pounds, and F, the acceleration, is measured in feet per second per second.

The same expression will hold for the accelerating force measured in grams weight, when M is the mass in grams and F the acceleration in centimetres per second per second, provided that g is given the appropriate value 981. From a scientific standpoint, the use of *gravitational* units of force, such as is contemplated here, is open to the objection that the value of g varies to a slight extent with position on the earth's surface, and hence the weight of one pound or gram is not, strictly speaking, a constant quantity. In what follows, we shall assume that absolute units are employed, so that the relation between force, mass and acceleration is expressed by (22).

DEDUCTIONS FROM THE LAWS OF MOTION

Impulse and Momentum.—20. We have now given precise meaning to (22), and we proceed to deduce some consequences which follow from this equation, in virtue of kinematical relations which have been shown to hold between acceleration, velocity and "distance." Let us confine attention, in the first place, to motion in a straight line, which we may take to be parallel to Ox. If P is the force in this direction, M the mass of the body considered, and f_x the acceleration produced, we have as in (22)

$$P = Mf_x.$$

Also, by the first of (12), $f_x = \dfrac{du}{dt}$.

Hence we may write $P = M\dfrac{du}{dt}$,

or (since M is constant) $P = \frac{d}{dt}(Mu)$. (25)

The quantity Mu, i.e., the product of the mass and velocity is termed the *momentum* of the body considered. We may express equation (25) in the statement that P, the *force* acting on a body, is equal to the rate of change of momentum.

Suppose now that P is maintained constant for an interval of time T. Then from (25), by integration, we deduce that

$$\int_0^T Pdt = PT = (Mu)_1 - (Mu)_0, \tag{26}$$

where $(Mu)_0$ and $(Mu)_1$ denote the values of the momentum at the beginning and end respectively, of the interval T. The product PT, viz., the product of the force and the time for which it acts, is termed the "time-effect" or *impulse*. We may express equation (26) in the statement that change of momentum is equal to the impulse of the applied force. When, on the other hand, P varies during the interval considered, this statement will still hold, provided that the term 'impulse' is applied to the integral $\int_0^T Pdt$, i.e., to the sum of the "time effects" of the applied force for all parts of that interval.

21. The significance of these ideas is apparent when we come to consider the behaviour of bodies which interact. According to the third law of motion (§ 18), if a force P is exerted at any instant upon one of two interacting bodies (A), then a force $-P$ is exerted at the same instant upon the other interacting body (B). Let M_A and u_A denote the mass and velocity of A: then we have, as in (25),

$$P = \frac{d}{dt}(M_A u_A). \tag{27}$$

Similarly, if M_B and u_B denote the mass and velocity of B, we have

$$-P = \frac{d}{dt}(M_B u_B). \tag{28}$$

By addition of (27) and (28), we deduce that

$$0 = \frac{d}{dt}(M_A u_A) + \frac{d}{dt}(M_B u_B),$$

and hence, by integration,

$$M_A u_A + M_B u_B = \text{const.}; \tag{29}$$

i.e., the total momentum of two bodies is not affected by interaction.

If external forces act in addition, these will produce effects which are represented by (26). If P_A is the external force on A, and P_B the external force on B, we deduce from this equation that

$$\int (P_A + P_B)dt = (M_A u_A + M_B u_B)_1 - (M_A u_A + M_B u_B)_0;$$

i.e., the total impulse of the externally applied forces is equal to the change produced in the total momentum of a system of two masses (A and B). It is not difficult to see that this statement may be generalized for a system containing any number of masses.

22. Next, instead of motion in a straight line, let us consider motion of the most general type. The resultant force P on the body can be resolved, at any instant, into three component forces X, Y, Z, and (§ 16) we may write

$$X = Mf_x = M\frac{du}{dt}, \tag{30}$$

a relation similar to (24). As in § 20, we may deduce that

$$\int Xdt = (Mu)_1 - (Mu)_0; \tag{31}$$

i.e., the impulse of the component force X, which acts in the direction Ox, is equal to the change in (Mu), the momentum in that direction.

Again, we can prove as before, for any system of masses, that the total impulse of the externally applied forces in any direction, is equal to the total change of momentum in that direction; i.e., the total momentum of a system, in any direction, is unaffected by interactions between the masses which compose it; this is the *principle of linear momentum*.

We observe that momentum, like velocity, is a quantity which can be resolved and compounded according to the vector law. If u, v, w are the components of a total velocity q, the total momentum of the body is measured by Mq, and Mu is the resolved part of this total momentum in the direction of Ox.

"Centre of Mass" of a System.—23. These results can be expressed in another way. According to our definition, the resolved part of the total momentum, in the direction Ox, of a system of masses M_A, M_B, M_C, $\cdots$ etc. is given by

$$M_A u_A + M_B u_B + M_C u_C + \cdots,$$

$$= M_A\frac{dx_A}{dt} + M_B\frac{dx_B}{dt} + M_C\frac{dx_C}{dt} + \cdots, \text{ by (7)},$$

$$= \frac{d}{dt}[M_A x_A + M_B x_B + M_C x_C + \cdots], \tag{32}$$

since the masses M_A, M_B, M_C, $\cdots$ etc. are severally constant. Let $\overline{M}$ be the total mass of the system, so that

$$\overline{M} = M_A + M_B + M_C + \cdots \text{ etc.},$$

and let $\bar{x}$ be defined by the equation

$$\overline{M}\bar{x} = M_A x_A + M_B x_B + M_C x_C + \cdots \text{ etc.} \tag{33}$$

Then, according to (32), the total momentum of the system in the direction Ox may be expressed in the form

$$\frac{d}{dt}(\overline{M}\bar{x}),$$

or, since $\overline{M}$ is constant, as

$$\overline{M}\frac{d\bar{x}}{dt} = \overline{M}\bar{u} \text{ (say)}. \tag{34}$$

We conclude that $(\overline{M}\bar{u})$, and therefore $\bar{u}$, will be unaffected by interactions between A, B, C, $\cdots$ etc.; so that $\bar{u}$, the velocity of the point defined by $\bar{x}$, will be constant if no external forces act on the system. When external forces X_A, X_B, X_C, $\cdots$ etc. act on M_A, M_B, M_C, $\cdots$, their total impulse in any interval will be equal to the change in $(\overline{M}\bar{u})$. Hence, by differentiation, we obtain the relation

$$X_A + X_B + X_C + \cdots = \frac{d}{dt}(\overline{M}\bar{u})$$

$$= \overline{M}\frac{d\bar{u}}{dt} = \overline{M}\frac{d^2\bar{x}}{dt^2}. \tag{35}$$

If Y_A, Y_B, Y_C, $\cdots$ etc. and Z_A, Z_B, Z_C, $\cdots$ etc. are component forces in the directions of y and z respectively, we find in the same way that

$$\left.\begin{aligned} Y_A + Y_B + Y_C + \cdots &= \overline{M}\frac{d\bar{v}}{dt} = \overline{M}\frac{d^2\bar{y}}{dt^2}, \\ Z_A + Z_B + Z_C + \cdots &= \overline{M}\frac{d\bar{w}}{dt} = \overline{M}\frac{d^2\bar{z}}{dt^2}, \end{aligned}\right\} \tag{36}$$

where $\bar{y}$, $\bar{z}$, $\bar{v}$, $\bar{w}$ are defined by equations similar to (33) and (34).

Now (35) and (36) are precisely the equations which we should obtain for the motion of the point whose co-ordinates are $\bar{x}$, $\bar{y}$, $\bar{z}$, if we imagined the whole mass $\overline{M}$ of the system to be concentrated at this point, and to be acted upon by the resultant of all the given external forces, i.e., by a force whose components are

$$(X_A + X_B + X_C + \cdots),\ (Y_A + Y_B + Y_C + \cdots),\ (Z_A + Z_B + Z_C + \cdots).$$

If these components are severally zero, we shall have from (35) and (36)

$$\frac{d\bar{u}}{dt} = \frac{d\bar{v}}{dt} = \frac{d\bar{w}}{dt} = 0;$$

i.e., the point $\bar{x}$, $\bar{y}$, $\bar{z}$, will move with constant velocity in a straight line.

The point $\bar{x}$, $\bar{y}$, $\bar{z}$, defined as above, is termed the *centre of mass* (or "mass-centre") of the system. We shall find that it has addi-

tional significance when we come to consider the science of *statics* (sec. 47).

Work and Energy.—24. According to the rules of differentiation, we may write the first of equations (12) in the form

$$f_x = \frac{du}{dt} = \frac{du}{dx}\frac{dx}{dt},$$

and then, by (7), we have

$$f_x = u\frac{du}{dx} = \frac{1}{2}\frac{d(u^2)}{dx}. \qquad (37)$$

So we may write equation (30) in the alternative form

$$X = \tfrac{1}{2}M\frac{d(u^2)}{dx},$$

$$= \frac{d}{dx}(\tfrac{1}{2}Mu^2), \text{ since } M \text{ is constant.}$$

Integrating, we have the equation

$$\int_0^1 X dx = [\tfrac{1}{2}Mu^2]_1 - [\tfrac{1}{2}Mu^2]_0, \qquad (38)$$

in which the suffixes 0 and 1 relate to the beginning and end, respectively, of the displacement considered.

If X has a constant value throughout the displacement, the integral on the left of (38) is equivalent to $X(x_1 - x_0)$, *i.e.*, to the product of the force and of the distance through which it acts. We call this quantity the *space-effect* of X, or the work done by X, in the displacement considered: if the displacement had been opposite in sense to the force, so that this product had had a negative value, we should have said that work was done *against* the force. When X varies during the displacement, we may say that the total work done by X is the sum of its space-effects for all parts of that displacement; *i.e.*, the total work will still be represented by the integral in (38).

25. If we confine attention, in the first place, to motion in a straight line parallel to Ox, the quantity $\frac{1}{2}Mu^2$ is one-half the product of the mass and of the square of its resultant velocity. This quantity is termed the *kinetic energy* of the moving mass. Accordingly, in this case, we may express equation (38) by saying that the *work* done by the applied force is equal to the increase of kinetic energy.

26. In the general case of motion in three dimensions, we have, corresponding to (38), the additional equations

$$\int_0^1 Y dy = [\tfrac{1}{2}Mv^2]_1 - [\tfrac{1}{2}Mv^2]_0,$$

and

$$\int_0^1 Z dz = [\tfrac{1}{2}Mw^2]_1 - [\tfrac{1}{2}Mw^2]_0,$$

when Ox, Oy, Oz are a rectangular system of axes. Then u, v, w are the three perpendicular components of a resultant velocity q (say), and it follows from the vector law for velocities (§ 6) that

$$u^2 + v^2 + w^2 = q^2.$$

Hence, by addition of the foregoing equations with (8), we deduce that, in a displacement of the mass M from the point (x_0, y_0, z_0) to (x_1, y_1, z_1),

$$\int_0^1 (X dx + Y dy + Z dz) = [\tfrac{1}{2}Mq^2]_1 - [\tfrac{1}{2}Mq^2]_0, \qquad (39)$$

and $[\frac{1}{2}Mq^2]$ is now, by our definition, the *kinetic energy* of the moving mass.

Equation (39) may be expressed by the same formula as (38), if we make a suitable extension (to cover motion in three dimensions) to our definition of "work." In general the displacement of a body will not be along the line of action of the force which acts upon it. Suppose then that the displacement is from A to B (fig. 9), and that AB is inclined at an angle θ to the line of action of the resultant force P; let BN be perpendicular to this line of action. If AB is indefinitely small, we may take P to remain constant, both in magnitude and direction, during the displacement from A to B; and if dx, dy, dz are the components of this very small displacement, and X, Y, Z the components of P, in the directions Ox, Oy, Oz, respectively, it may be shown that

$$X\ dx + Y\ dy + Z\ dz = PAN = PAB\ \cos\theta \qquad (40)$$

According to the vector law, AN is the resolved part of the displacement AB in the direction of P. We take the product $(P{\cdot}AN)$ to be a measure of the work done by P in the displacement AB; *i.e.*, we now take as our generalized definition of "work" (*cf.* § 24) the product of the force and of the resolved part of the displacement in the direction of the force. With this definition, according to (40), the integral on the left of equation (39) measures the total work done in the displacement from (x_0, y_0, z_0) to (x_1, y_1, z_1); so we may assert, generally that in any displacement of a body, the work done by the applied force is equal to the increase in kinetic energy.

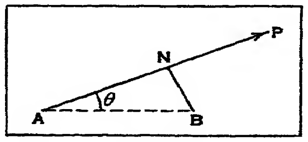


FIG. 9

27. Now let us imagine that the force on a mass M_A is due to interaction with a second mass M_B. Then if X is the component force on M_A, there will be, at the same instant, a force $-X$ acting on M_B. Let dx_A be the displacement of M_A in a very small interval of time, and dx_B the displacement of M_B in the same interval. According to § 24, we shall have

$X\,dx_A$ = change, during this interval, in the quantity $\frac{1}{2}M_A u_A^2$,

$-X\,dx_B$ = change, during this interval, in the quantity $\frac{1}{2}M_B u_B^2$.

and hence, by addition,

$$X(dx_A - dx_B) = \text{change, during the interval, in the quantity } \tfrac{1}{2}(M_A u_A^2 + M_B u_B^2) \qquad (41)$$

Suppose, in the first place, that the motion of both masses is confined to the direction Ox. Then if M_A and M_B move through the *same* distance (so that $dx_A = dx_B$), equation (41) may be expressed in the statement that interaction does not affect the total kinetic energy of the two masses; and it is evident that this conclusion may be generalized for a system containing any number of masses. The total kinetic energy however will be altered by interaction if the distance between A and B does not remain constant during the displacement: *e.g.*, if a bullet be fired into a block of wood, the forward pressure on the wood is equal to the backward pressure on the bullet; but, since the bullet penetrates the wood, its forward displacement in any interval of time is less than that of the wood; so less work is done by the forward pressure than is done against the backward pressure, and the total kinetic energy of the wood and bullet is decreased as a consequence of the interaction.

Particles, and "Rigid Dynamics."—28. A similar conclusion holds for motion in general. The total kinetic energy of a system of masses will in general be changed as a result of interaction; but the total kinetic energy will not change, if the distance between any two masses remains constant, and if the forces due to their interaction act along the line which joins them.

We are here thinking of bodies so small that their masses may be imagined as concentrated in points. Such bodies are termed *particles*, and bodies of finite size are commonly treated, in dynamics, as made up of large numbers of particles (*cf.* § 53). We see from the foregoing discussion that special simplification will be possible if we assume that the distance between any two of the particles composing a body is invariable, *i.e.*, that the body is *rigid;* for then we can say that its kinetic energy, like its momentum, is unaffected by interaction between the constituent particles. This is the basic assumption of *rigid dynamics*.

Moment of Momentum.—29. We have defined the momentum of a body (§ 20) as the product of its mass and velocity. Let M be the mass of a particle at A (fig. 10), and let q, the resultant velocity, be along a line AB in the plane of the diagram. Let O be another point in the same plane, and let p denote the distance of O from the line AB. Then the quantity Mqp, *i.e.*, the product of the momentum of the particle and the distance of its line of action from O, is termed the *moment of momentum* of the

particle about O. It is usual to consider moment of momentum as positive when (as in fig. 10) the point O would be on the left hand of a man moving with the particle.

Let perpendicular axes Ox, Oy be taken through O, and let $x(=AM)$ and $y(=AN)$ be the coordinates of A, and u, v the components of the resultant velocity q, relative to these axes. Then it will be seen (fig. 10) that

$$\begin{aligned} M(xv-yu) &= Mq(x\sin\theta-y\cos\theta) \\ &= Mq(ML-MK), \qquad (42) \\ &= Mqp. \end{aligned}$$

The moment of momentum of the particle about O is accordingly measured by $M(xv-yu)$, and hence its rate of change (since M is constant) is measured by

$$\begin{aligned} M\frac{d}{dt}(xv-yu) &= M\left\{\left(x\frac{dv}{dt}+v\frac{dx}{dt}\right)-\left(y\frac{du}{dt}+u\frac{dy}{dt}\right)\right\} \\ &= M(xf_y-yf_x), \qquad (43) \end{aligned}$$

by (7), (8) and (12).

However (§ 15) the existence of component accelerations f_x, f_y implies the existence of component forces X, Y, where

$$X=Mf_x, \quad Y=Mf_y.$$

Hence, according to (43), the rate of change of moment of momentum is measured by $(xY-yX)$. If

$$xY-yX=0 \qquad (44)$$

this rate of change is zero.

Now (44) will be satisfied, not only when no force is acting on the particle (so that $X=Y=0$), but also when

$$\frac{X}{Y}=\frac{X}{Y};$$

i.e., (according to the vector law), when the resultant force on the particle acts along the line OA. Hence, if a particle is subjected to forces whose resultant always acts through a fixed point O, its moment of momentum about O will remain unchanged.

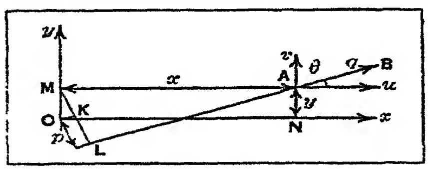


FIG. 10

30. In the general case we can show, as in (42), that $(xY-yX)=Pp'$, where P is the resultant force on the particle, and p' is the distance of O from the line of action of P. The product Pp' is termed the *moment* about O of the resultant applied force P. Thus we may express (43) by saying that the moment of the applied force about any point is equal to the rate of change of moment of momentum about that point.

Again, if the force P on a body A is due to interaction with a second body B, then by the third law of motion (§ 18) there must act, simultaneously, an equal and opposite force $(-P)$ on B. As in § 21, we may show that the total moment of momentum of two bodies is not affected by interaction, and we may generalize this result for any system of bodies: the resultant (or total) moment about any point of the external forces which act on a system is equal to the rate of change of the total moment of momentum of that system, about the same point; this is the *principle of angular momentum.*

ORBITS DESCRIBED ABOUT A CENTRE OF FORCE

31. The problem confronting Newton, for which he developed his system of dynamics, was to explain the motion of the heavenly bodies— the paths, or *orbits,* which they describe in relation to the earth. His explanation is based on the assumption of "universal gravitation"; *i.e.*, of mutual attraction between any two bodies, depending in intensity upon their masses and upon their distance apart.

If an attractive force of this kind acts between two bodies A and B, it will affect the motion of both. We have seen however (§ 23) that their *mass centre* will move with constant velocity in a straight line, notwithstanding the interaction between them, if (as we here assume to be the case) no other force is operative. Now in the case of two *particles* situated at points A and B, the mass centre lies in the line AB, *i.e.*, on the line of action of the forces of attraction. So to investigate the motion of either particle in relation to the mass centre, we need not consider the other particle: the first problem for discussion is the motion of a single particle A about a point O, where it is attracted to O with a force depending upon the distance OA. We call O the *centre of attraction.*

32. An argument similar to that of § 9 shows that the orbit will be confined to a single plane through O. Let v be the resultant velocity of the particle when its distance from the centre of attraction is r, and let p be the distance of O from AT (fig. 11), the instantaneous direction of this velocity. Then, since the force on the particle always acts through O, we know (§ 29) that the moment of momentum of the particle about O will not change; *i.e.,* since the mass is constant, we may write

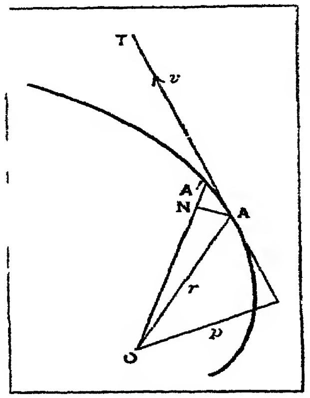


FIG. 11

$$pv = \text{const.} = h \text{ (say)}. \qquad (45)$$

33. Again, in a very small displacement from A to A' (fig. 11), if the distance from O is increased by a small quantity $A'N$ $(=dr)$, and if P is the force of attraction, then (§ 24) work of amount (Pdr) is done against P, and the increase in kinetic energy during this displacement is accordingly given by $(-Fdr)$. If m is the mass of the particle, it follows that in passing by any path from a point distant r_o to a point distant r from O, the velocity will change from v_o to v, where

$$\tfrac{1}{2}mv^2-\tfrac{1}{2}mv_0^2=-\int_{r_0}^{r}Fdr. \qquad (46)$$

The force F depends, by assumption, solely on the distance r. So we may write

$$F=m\phi(r), \qquad (47)$$

where $\phi(r)$ is some function of r. Equation (46) may then be written in the form

$$v^2-v_0^2=-2\int_{r_0}^{r}\phi(r)dr,$$

or

$$v^2+2\int^{r}\phi(r)dr=\text{const.}, \qquad (48)$$

where $\phi(r)$ is to be interpreted, from (47), as the acceleration imposed upon the particle, by the force of attraction. This relation, when $\phi(r)$ is known, gives v in terms of r: like (45), it must be satisfied at all points in the orbit.

34. Combining (45) and (48) we have

$$\frac{h^2}{p^2}+2\int^{r}\phi(r)dr=\text{const.}, \qquad (49)$$

a relation between p and r which is independent of dynamical quantities, and serves to determine the *shape* of the orbit. When $\phi(r)$ is known, the integral can be evaluated, and then (49) gives the equation of the orbit in the *tangential-polar* form.

The Orbit for the "Inverse Square" Law.—35. Thus, if we take $\phi(r)$ to be given by Newton's *inverse square law of attraction;* viz.,

$$\phi(r)=\frac{\mu}{r^2}, \text{ where } \mu \text{ is constant,} \qquad (50)$$

equation (49) takes the form

$$\frac{h^2}{p^2}=\frac{2\mu}{r}+C. \qquad (51)$$

This may be recognized as the tangential-polar equation of a *conic* with respect to a *focus* as origin. The three forms of conic are the ellipse, the parabola and the hyperbola: for the ellipse the equation is

$$\frac{l}{p^2} = \frac{2}{r} - \frac{1}{a},$$

and for the hyperbola

$$\frac{l}{p^2} = \frac{2}{r} + \frac{1}{a},$$

where, in each case, l denotes the *semi-latus rectum* and a the length of the *semi-axis* containing the focus in question; in the parabola, a is infinitely great, and we have the equation

$$\frac{l}{p^2} = \frac{2}{r},$$

Comparing these equations with (51), we see that there is exact correspondence provided that

$$l = \frac{h^2}{\mu}, \quad a = \mp \frac{\mu}{C}. \tag{52}$$

Hence the orbit will be an ellipse, parabola or hyperbola according as C, in (51) is negative, zero, or positive. In any case the semi-latus rectum of the orbit will be given by the first of (52). A positive value of C implies a positive value of the constant on the right of (48), and hence, if we substitute from (50), a value of v^2 greater than $\frac{2\mu}{r}$. Thus, if at any point in an orbit

$$v = \sqrt{(2\mu/r)} = V(\text{say}), \tag{53}$$

that orbit is a parabola; if $v < V$ it is an ellipse, and if $v > V$ it is a hyperbola. We see that V is the velocity which must be possessed by the particle in order that its orbit may go to an infinite distance from the centre of attraction; it is termed the *critical velocity* corresponding to the distance r.

Newton's Law of Gravitation.—36. We have assumed in the preceding paragraph that the attractive force on the particle varies inversely as the square of its distance from the centre of attraction. When the force is due to the attraction of a second particle, this is equivalent to assuming that the attraction varies inversely as the square of the distance between the two particles.

Newton's "law of universal gravitation" asserts that a mutual attraction, satisfying this relation, is exerted between every pair of particles in the material universe. If two particles have masses m, m', it asserts that the force of their mutual attraction, when their distance apart is r, will be

$$\frac{\gamma m m'}{r^2},$$

where γ is a universal constant, called the constant of gravitation.

That branch of mechanics known as the *"theory of attractions"* is concerned with the consequences of this law in regard to the attractions of bodies of finite extent; *i.e.*, bodies composed of a large number of particles. One result may be stated here: a spherical body (either solid or hollow), of which the density is the same for all points at the same distance from its centre, exerts the same attraction on any particle or body outside it as would be exerted by a particle of the same total mass, situated at its centre. Thus in calculating, *e.g.*, the motion of a planet under the attraction of the sun, we may replace each body by a particle of equal mass. The investigation of § 35 relates directly to this problem, if we assume (as is very nearly true) that the sun's mass is so large, in relation to that of the planet, that the centre of the sun can be identified with the mass-centre of the two, *i.e.*, with the *centre of attraction*. More elaborate investigations, by Newton and his successors, have taken account of the attractions of the planets on the sun and on one another: they have abundantly confirmed the accuracy of the inverse square law, by showing that it is able to explain the actual motions of the planets in minute detail.

STATICS

Statics treats of forces at rest and therefore in equilibrium. The second law of motion is: *"Change of motion is proportional to the moving force impressed and takes place in the direction in which the force acts."* By change of motion, Newton meant *change in momentum* as his own explanation of the law indicates. He explains this law as follows: "If a force generate any motion, a double force will generate a double motion, a triple force, a triple motion, whether they be applied simultaneously and at once, or gradually and successively. This motion, if the body were already moving, is either added to the previous motion, if in the same direction, or subtracted from it, if directly opposed, or compounded with it if the two motions are inclined at an angle."

37. According to Newton's second law of motion, the possession by a mass M of an acceleration F in any direction implies that a force P, given by

$$P = MF,$$

is acting in that direction. As a deduction from this law, it was shown (§ 16) that forces can be resolved or compounded according to the vector law. Combining these results, we observe that a body can remain at rest (that is, it can have zero acceleration), either because it is entirely free from the action of force (§ 14), or because the forces which act upon it have no resultant, *i.e.*, neutralize one another when combined by the vector law. The former condition cannot be contemplated in a universe characterized by universal gravitation: the second is the concern of statics—the science of forces in balance, or *equilibrium*.

EQUILIBRIUM OF A PARTICLE

Polygon of Forces.—38. We start by considering a particle, *i.e.*, a body of infinitesimal size. Suppose first that two forces are acting, represented in direction and magnitude by lines OP_1, OP_2 (fig. 12) passing through O, the particle. According to the vector law, their resultant will be represented by OR_1, the diagonal of the parallelogram of which OP_1, OP_2 are the sides: it follows that the point R_1 could have been found by drawing OP_1 to represent the first force and P_1R_1 to represent the second.

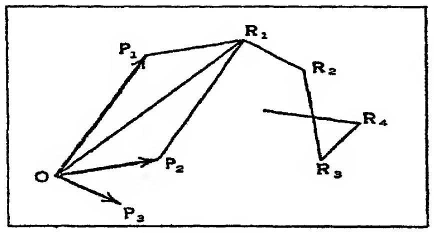


FIG. 12

If a third force acts in addition, represented by OP_3, the resultant of the three forces is the resultant of OP_3 and OR_1. By the same argument, it will be represented by OR_2, where R_1R_2 is drawn (parallel and equal to OP_3) to represent the third force. The process can be repeated for any number of forces: we obtain points such as R_3, R_4, . . . etc., and the successive resultants will be represented by OR_1, OR_2, OR_3 . . . etc. It is however a condition of equilibrium that the resultant of all the forces shall be zero; so we see that the last of the points obtained in this way must coincide with O. That is to say, if OP_1, P_2R_1, R_1R_2, . . . etc. are drawn to represent all the forces which act on a particle in equilibrium, these must be sides of a *closed* polygon, which is called the *polygon of forces*. The order in which the forces are taken is evidently immaterial, and the polygon is not necessarily confined to one plane.

In the special case of two forces, we see that R_1 must coincide with O, if the forces are to be in equilibrium. Clearly, this can only occur when the forces are equal and opposite, with the same line of action.

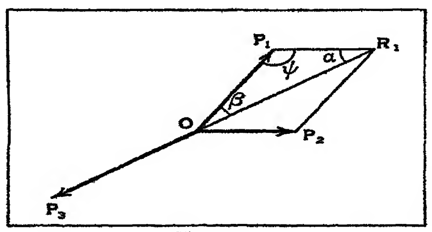


FIG. 13

Triangle of Forces.—39. If the particle is in equilibrium under three forces, represented by OP_1, OP_2, OP_3, the same argument shows that OP_3 must be equal and opposite to OR_1. In words, the three forces must be represented by the sides of a triangle (OP_1R_1) taken in order.

Lamy's Theorem.—40. Fig. 13 illustrates this case. We have, as just stated,

$$\frac{P_1}{OP_1} = \frac{P_2}{P_1R_1} = \frac{P_3}{R_1O}.$$

But, by a property of the triangle,

$$\frac{OP_1}{\sin\alpha} = \frac{P_1R_1}{\sin\beta} = \frac{R_1O}{\sin\gamma}.$$

Hence we deduce that each force is proportional to the size of the angle between the other two forces. This theorem is due to B Lamy (1679).

BODIES OF FINITE SIZE

Transmissibility of Force.—41. Forces imposed upon the same particle are necessarily concurrent; *i.e.*, their lines of action must intersect at a common point. The same is not true of forces which act upon a body of finite size: to specify any such force completely, we must state not only its line of action, magnitude and sense but also its point of application. It will be realized that actual bodies distort when forces are applied, and that definite particles, in consequence, alter their relative positions

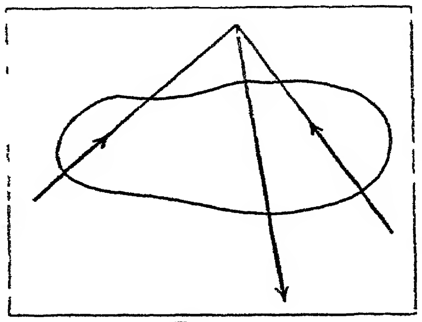


FIG. 14

On the other hand, the distortion is generally small, and for many purposes it may be neglected. Statics commonly treats of bodies as rigid, and it makes use of an assumption which can be regarded as intuitive, viz., that any point in a body, lying on the line of action of a force, may be regarded indifferently as the point of application. This is the *principle of transmissibility of force;* it enables us, in effect, to concentrate upon forces, without particular reference to the body upon which they act.

42. Thus, if *three* forces combine to maintain equilibrium in a body of any size, we may assert, quite generally, that they must be concurrent. This theorem will be seen to follow directly from the condition for two forces which was stated at the end of § 38: the third force must be equal and opposite to the resultant of the other two, and therefore it must act through their point of intersection. As fig. 14 indicates, the point at which three forces intersect will not necessarily fall within the body upon which they act.

Parallel Forces.—43. The principle of transmissibility of force can be employed to find the resultant of two *parallel* forces —a case which does not fall directly within the scope of the vector law. It is evident that the effect of a given system of forces will not be altered by the addition of two equal and opposite forces having the same line of action. If then P and Q (fig. 15) are the two parallel forces whose resultant is required, we may superpose two equal and opposite forces of magnitude S, acting, as

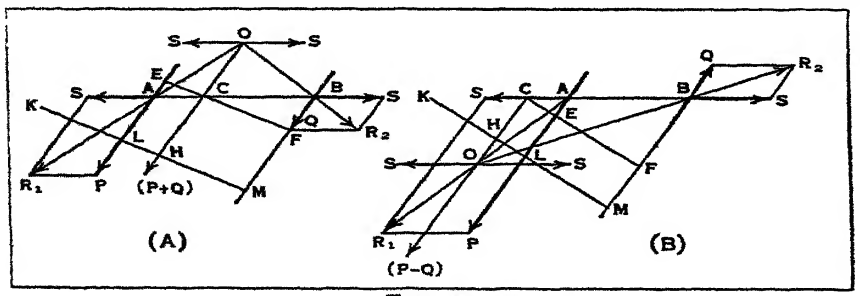


FIG. 15

shown, along a line AB which cuts the line of action of P and $Q;$ and we may combine, according to the vector law, one of these forces with P and the other with Q.

The resultant of P and S is a force R_1, and the resultant of Q and S is a force R_2. In general, the lines of action of R_1 and R_2 will intersect, as shown, at some point O, and according to the principle of transmissibility this point may be regarded as the point of application both of R_1 and R_2. If we now replace R_1 by forces P and S, and R_2 by forces Q and S, acting through O as shown, the two forces S will again neutralize. So we are left, finally, with forces P and Q acting through O in a direction parallel to the original lines of action of P and $Q;$ and it follows that OC is the line of action of the required resultant.

Two cases demand examination, shown in diagrams (A) and (B), respectively, of fig. 15. In the first case, P and Q have the same sense, and C lies between A and $B:$ in the second, P and Q are opposite in sense, and C lies outside AB, on the side of the greater force P. In either case we have

$$\begin{aligned}\frac{CA}{CB} &= \frac{CA}{OC} \div \frac{CB}{OC},\\ &= \frac{S}{P} \div \frac{S}{Q} \text{ (by the vector law),} \qquad (54)\\ &= \frac{Q}{P}.\end{aligned}$$

The magnitude of the resultant force is evidently $(P+Q)$ in the first case and $(P-Q)$ in the second; its sense is in both cases that of P_1, *i.e.*, the greater of the forces P and Q.

Thus one problem is solved, except in the special case in which P and Q are equal in magnitude and opposite in sense. In this case, according to (54), the point C is an infinite distance from A and B, and the magnitude of the resultant is zero: in effect, we cannot find a single force which will replace a pair of equal and opposite parallel forces whose lines of action are not coincident. A pair of forces of this nature is said to constitute a *couple*.

Moments.—44. Equation (54) admits of interpretation in accordance with the concept, moment of a force, which was introduced in § 30. If we draw a line EF through C, perpendicular to the lines of action of P and Q, we have at once, from the figure,

$$\frac{CE}{CF} = \frac{CA}{CB}, \quad = \frac{Q}{P}, \quad \text{by (54).}$$

This equation may be written in the form

$$PCE = QCF, \qquad (55)$$

and in this form it may be expressed in the statement, that the moments of P and Q about C, according to the definition of § 30, are equal and *opposite; i.e.*, the resultant moment of P and Q about C is zero.

The forces P and Q evidently have the same moments about any other point H in OC, the line of action of their resultant. Conversely, if the resultant moment of two parallel forces about any two points is zero, their resultant must act along a line which passes through those two points, and is therefore definite. We might, in fact, have determined the resultant of P and Q in this way.

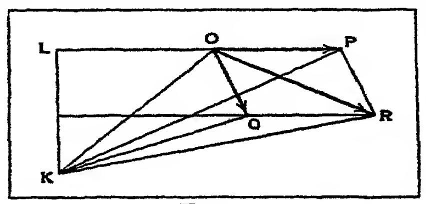


FIG. 16

45. Now consider the moment of the resultant force about any other point K in the plane of the forces. When the forces P and Q have the same sense (diagram A), their resultant is a force of magnitude $(P+Q)$, and its moment about K is given by

$$\begin{aligned}(P+Q)KH &= P(KL+LH)+Q(KM-HM)\\ &= PKL+QKM, \qquad (56)\end{aligned}$$

by (55), since $LH=EC$ and $HM=CF$.

When P and Q are opposite in sense (diagram B), their resultant is a force of magnitude $(P-Q)$, and its moment about K is given by

$$\begin{aligned}(P-Q)KH &= P(KL-HL)-Q(KM-HM),\\ &= PKL-QKM, \text{ by (55) again.} \qquad (57)\end{aligned}$$

46. In both cases we see that the sum of the moments of P and Q about K (taken with due regard to sign) is equal to the moment of their resultant about the same point. The same theorem is true of two forces which intersect (fig. 16). The moment of P about K is PKL, *i.e.*, it is measured by twice the area of the triangle $KOP;$ and similarly, the moments of Q and R

are measured by twice the areas of the triangles KOQ and KOR respectively. Since, however, $QR=OP$, the triangle KOP is equal in area to the sum of the triangle OQR and KQR: therefore the sum of the triangles KOP, KOQ is equal in area to the triangle KOR; *i.e.*, the sum of the moments of P and Q about K is equal to the moment of their resultant R about the same point.

This theorem can be extended to any number of forces, whether parallel or intersecting. In the case of two parallel forces constituting a couple (§ 43), the total moment about any point in their plane has a constant value, given by the product of either force with the distance between their lines of action.

Centre of Gravity.—47. The total weight of a body (*i.e.*, the force exerted upon it by the attraction of the earth) is the resultant of forces exerted upon all the particles which go to form that body. When its dimensions are small in comparison with those of the earth, the force on each particle is proportional to its mass, and all the forces may be taken as parallel: under these conditions we may show that the weight of a rigid body acts always through a point fixed in relation to the body.

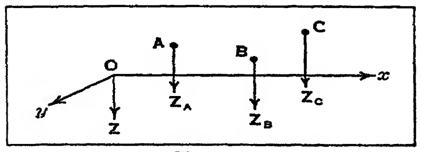


FIG. 17

Let Ox, Oy, Oz be three perpendicular axes fixed in relation to the body, and consider the components in the direction Oz of the forces which act upon three particles A, B, C, of mass M_A, M_B, M_C. Whatever be the direction of the resultant forces on the particles, these components also will be proportional to the respective masses; so we may take them to be given by

$$Z_A=kM_A,\quad Z_B=kM_B,\quad Z_C=kM_C.$$

where k is a constant; and if x_A, x_B, x_C are the distances of A, B, C from the plane yOz, the moments of Z_A, Z_B, Z_C about the axis Oy will be $Z_A\ x_A$, $Z_B\ x_B$, $Z_C\ x_C$. Therefore the resultant moment about Oy will be

$$k(M_Ax_A+M_Bx_B+M_Cx_C). \tag{58}$$

By a generalization of the theorems stated above, the resultant of Z_A, Z_B, Z_C will be a parallel force of magnitude

$$(Z_A+Z_B+Z_C)=k(M_A+M_B+M_C),$$

and its moment about Oy must be equal to (58). Therefore the distance from yOz of its line of action will be $\bar{x}$, where

$$k(M_A+M_B+M_C)\,\bar{x}=k(M_Ax_A+M_Bx_B+M_Cx_C).$$

Generalizing this result for any number of particles constituting a total mass $\overline{M}$, we obtain the formula (33) of § 23; and applying the same argument to moments about the axes Oz and Ox, we find that the resultant of all the forces on all the particles, *i.e.*, the total weight, will in every case pass through a point $(\bar{x}_x, \bar{y}_y, \bar{z}_z)$ which in that article was termed the *mass centre* of the system. In its present significance it is termed the *centre of gravity* of the system, *i.e.*, of the body which the particles compose.

Equilibrium Under Gravity.—48. The motion of centre of gravity—as a point, fixed in relation to any given body, through which its weight may be taken to act—enables us to bring many problems within range of the theorem stated in § 42. For example, suppose that we require to know the slope at which a heavy rod AB (fig. 18) can rest in equilibrium with its ends on two smooth plane surfaces CA, CB. Since the effect of gravitation may be represented by a single force through G, the centre of gravity of the rod, this is in effect a problem of equilibrium under three forces. We know that R_A and R_B, the forces exerted by the plane surfaces, must intersect in a point vertically above G; moreover, since these surfaces are smooth, R_A and R_B must be perpendicular to CA and CB respectively. Hence, when the position of G in AB is known, we have only to draw lines OA, OG, OB in three known directions, and to place AB so that it is divided by these lines into segments which have a definite ratio: when this condition is satisfied, AB has the required slope.

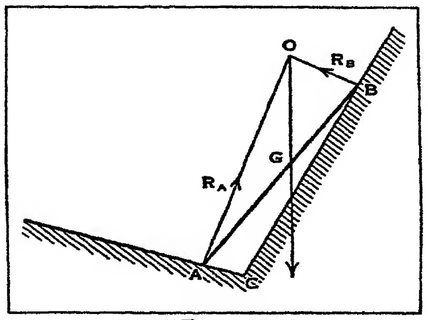


FIG. 18

Catenaries.—49. Again, we may employ the theorem to calculate the curve in which a heavy chain AB (fig. 19) will hang in equilibrium under gravity, and the tensions which will be brought into play. Since the chain is flexible, the tension at every point will act along the tangent to the curve. Let T be the tension at any point P, and H the tension at the lowest point O. The portion of the chain which extends between O and P may be regarded as held in equilibrium by three forces; viz., the tensions T and H, acting in the directions CP, CO, as indicated, and the resultant weight of the portion OP. Since these three forces must be concurrent, the centre of gravity of the portion OP must lie in the vertical line through C; the triangle PCN (fig. 19) will be the triangle of forces (§ 39); and if W is the weight of the portion OP, we have

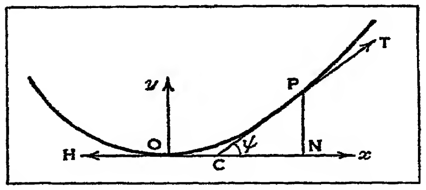


FIG. 19

$$\frac{W}{PN}=\frac{H}{CN}=\frac{T}{CP}. \tag{59}$$

Let Ox, Oy be drawn horizontally and vertically through O, and let s denote the length of the curve measured from O. Then we have, from (59),

$$W=H\tan\psi=H\frac{dy}{dx},$$

and hence
$$\frac{dW}{dx}=H\frac{d^2y}{dx^2}.$$

Now $\dfrac{dW}{dx}$, the rate at which the total weight W increases with the horizontal distance ON, is the weight of the chain per unit horizontal run. If w is the weight of the chain per unit length (this quantity may of course vary along the length of the chain) we have

$$\frac{dW}{dx}=w\frac{ds}{dx}=w\sqrt{\left[1+\left(\frac{dy}{dx}\right)^2\right]}.$$

So we have, finally, the relation

$$\frac{w}{H}=\frac{\dfrac{d^2y}{dx^2}}{\sqrt{\left\{1+\left(\dfrac{dy}{dx}\right)^2\right\}}}, \tag{60}$$

as a differential equation from which the form of the curve may be deduced when w and H are specified. When the curve has been found, the tension T at any point can be found from (59); for we have

$$T=H\sec\psi=H\frac{ds}{dx}.$$

50. When the weight per unit horizontal run is uniform—as will be very approximately true of a uniform wire stretched in a flat curve—the centre of gravity of OP must lie above the middle point of OH. Hence we shall have

$$CN=\tfrac{1}{2}x,$$

or, by (59)
$$Hy=\frac{W}{2}x.$$

Since W is now proportional to x, we see that y will be proportional to x^2; *i.e.*, the chain will hang in a parabola.

Solid Friction.—51. Reverting to the problem discussed in § 48, we observe that the forces exerted on the rod by the surfaces CA, CB will not necessarily have directions perpendicular to those surfaces, unless the possibility of frictional forces is

expressly excluded. Allowance for friction is commonly made on the basis of the empirical law propounded by C. A. Coulomb (1781), according to which the force exerted between two surfaces may be inclined to their common normal at any angle which does not exceed a certain definite value λ. This limiting angle λ, termed the *angle of friction*, depends upon the nature of the surfaces in contact but is independent of the intensity of the reaction between them. On the basis of this law we may say, in the problem considered, that the rod can rest in any position (as shown e.g., in fig. 20), provided that a point D can be found vertically above G, such that neither of the angles DBO, DAO exceeds λ, where AO, BO are perpendicular to CA, CB respectively.

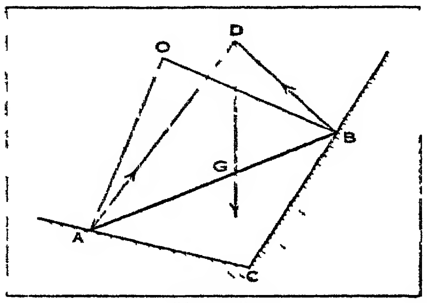


FIG. 20

52. Coulomb's law of friction may be stated in another way. If R is the normal pressure between two surfaces in contact, the resultant action is found by combining R with a tangential component S (due to friction); it will thus be inclined at an angle ϕ to the normal direction, where

$$\tan\phi = \frac{S}{R}.$$

Hence, if ϕ cannot exceed the angle of friction λ, it follows that the ratio S/R cannot exceed a definite limit, $\tan\lambda$, which is called the *coefficient of friction*, and is commonly denoted by the symbol μ. Thus, according to Coulomb's law, a tangential force will be exerted between two rough surfaces in contact, which cannot exceed a definite fraction μ of the normal pressure between them, but will assume, within these limits, any magnitude and direction that may be required to maintain equilibrium. As was shown by the preceding example, the exact nature of the forces which act to maintain equilibrium in a given position will generally be indeterminate.

DYNAMICS OF CONTINUOUS SYSTEMS

53. The purpose of this article is to explain, to a reader not previously conversant with mechanics, those basic concepts and principles of the science which he will require when reading other articles in this encyclopaedia, and in particular the article DYNAMICS.

54. Natural bodies, with which the general theory has to deal, are continuous or apparently continuous distributions of matter, either solid, fluid or gaseous. One way in which they may be treated is to conceive them as an aggregate of particles—large but finite in number, and separated by small but finite intervals—which act on one another with forces of direct attraction or repulsion. This is commonly known as *Boscovich's hypothesis* (R. G. Boscovich, a *Treatise on Natural Philosophy*, Venice, 1758): it enables us to formulate after the manner of §§ 22, 30, the principles of linear and angular momentum.

Principle of d'Alembert.—55. Another method of treatment is to assume a principle first stated by d'Alembert (J. le R. d'Alembert, *Traité de dynamique*, 1743). According to Newton's second law (§ 15) the possession of an acceleration F, in any direction, by a particle of mass M implies that a force of magnitude MF acts upon it in that direction. This force, which we may call the effective force, is the resultant of all the forces which act on the particle. When the particle forms part of a material "system," the latter forces may be divided into two classes: (1) the *external forces* acting from outside the system, and (2) the *internal forces* due to the reaction of other particles in the system. D'Alembert's principle assumes that the internal forces constitute by themselves a system in equilibrium, and hence, that the *effective forces* constitute a system which as a whole is statically equivalent to the system of external forces.

Accordingly we have, for any system, three equations of the type

$$\Sigma(m\ddot{x}) = \Sigma(X), \tag{61}$$

and three of the type

$$\Sigma(xm\ddot{y} - ym\ddot{x}) = \Sigma(xY - yX), \tag{62}$$

in which Σ denotes a summation embracing all the particles of the system. In these equations m denotes the mass of a typical particle, and x, y, z its coordinates referred to any rectangular system of axes, so that $m\ddot{x}$, $m\ddot{y}$, $m\ddot{z}$ are the components of the effective force on m; X, Y, Z are the components of the external force on this particle. Equation (61) is obtained by resolving parallel to Ox, and (62) by taking moments about Oz.

Writing (61) and (62) in the equivalent forms

$$\frac{d}{dt}\Sigma(m\dot{x}) = \Sigma(X) \tag{63}$$

$$\frac{d}{dt}\Sigma(xm\dot{y} - ym\dot{x}) = \Sigma(xY - yX) \tag{64}$$

we see that they express the principles of linear and angular momentum, which are thus shown to be derivable from either of the two fundamental assumptions just stated. It will be observed that neither principle is restricted to rigid bodies: the importance of assuming rigidity lies in the fact that it renders the six equations of types (63) and (64) sufficient in number to determine the motion of a body.

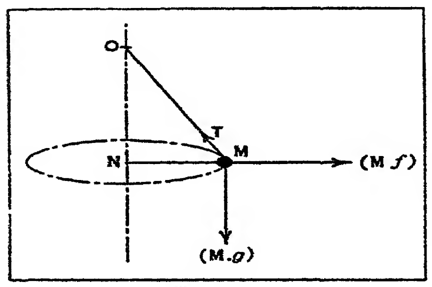


FIG. 21

56. An obviously equivalent statement of d'Alembert's principle is that the system of external forces is in equilibrium with the system of effective forces *reversed*. This concept enables us to treat problems in dynamics by the methods of statics. For example, in the problem of the conical pendulum (fig. 21) we have a mass M attached to a fixed point O by an inextensible string, and describing a circular path about a vertical axis through O. The circular motion can be shown to involve an acceleration of the mass along the radius MN, and if this acceleration has a constant value f we may take account of the motion by assuming a *reversed effective force*, of magnitude $M{\cdot}f$, to act as shown. Then we have, in effect, a problem in statics, since the reversed effective force must be in equilibrium with the external forces on M, viz., its weight $M{\cdot}g$ acting vertically and the force T imposed upon it by the tension of the string. (R. V. S.)

BIBLIOGRAPHY.—Text-books dealing with the elementary notions of mechanics, as outlined in this article, are very numerous: the reader may be referred to A. E. H. Love's *Theoretical Mechanics*, or to H. Lamb's *Statics, Dynamics* and *Higher Mechanics*. The last of these treatises deals with higher developments of the subject as outlined in the article DYNAMICS; E. T. Whittaker's *Treatise on Analytical Dynamics* may also be consulted. Philosophical aspects are treated in the first part of J. Ward's *Naturalism and Agnosticism*. For a short account of Newton's researches *cf.* S. Brodetsky, *Sir Isaac Newton*.

MECHANICVILLE, a city of Saratoga county, New York, U.S.A., on the State Barge canal and the west bank of the Hudson river, near the mouth of the Hoosick, 20 m. above Albany. It is served by the Boston and Maine (which has a large freight-classification yard here) and the Delaware and Hudson railways. Pop. (1920), 8,166; 7,924 in 1930. The city has abundant water-power, and manufactures brick, paper, paper boxes, shirts, knit goods, gloves and other articles. A dam provides power for the General Electric Company at Schenectady. The first settlement was made about 1680. The village was chartered by the county court in 1859, incorporated in 1870 and became a city in 1915.

MECHANISM is the general name for a theory which holds that natural phenomena can be and should be explained by reference to matter and motion and their laws. The term, however, is used in rather different senses in different contexts, according to the nature of the other view which it is intended to contradict. The principal antitheses are these: Mechanism *versus* Super-naturalism; Mechanism *versus* Teleology; Mech-

anism *versus* Vitalism; Mechanism *versus* Emergence. The enumeration follows more or less the historical order of the controversies which each pair of antithetic terms suggests. In the 17th century a great deal was written in favour of the "mechanical philosophy." "The tenets of mechanical philosophy," as Robert Boyle conceived it, consisted in explaining the physical phenomena of nature by means of "little bodies variously figured and moved." What the upholders of the "mechanical philosophy" were most concerned about was the elimination from science of such notions as "substantial forms," "occult qualities," "hypostatical principles," etc., which had long obstructed the path of natural knowledge. Boyle himself did not see any inconsistency in combining "mechanical" with teleological explanations or with the assumption that Nature has "designs." Spinoza, on the other hand, regarded the mechanical method of explanation as incompatible with the teleological and the supernatural. In view of the once prevalent proneness to explain natural phenomena teleologically, and teleologically only (which Voltaire still found it necessary to ridicule) the supporters of a mechanical, anti-teleological attitude in science no doubt rendered an important service. But the subsequent development of the biological sciences tended to show the inadequacy of a merely mechanical explanation of vital phenomena. While admitting the need of pursuing mechanical modes of explanation as far as possible, it has been felt with increasing urgency that something more is required to account for the facts of life than the laws of matter and motion. The opposition to biological mechanism, or mechanical biology, first took the form of what is known as Vitalism or the assumption that there is in each living organism a kind of entelechy (*q.v.*) or directive vital principle. This kind of vitalism was especially vindicated by H. Driesch. More recently Lloyd Morgan and others have advocated a theory of emergence (*q.v.*) in opposition not only to biological mechanism, but to the theory of exclusive mechanism even in chemistry and other physical sciences. In its application to biology, the doctrine of emergence has been called emergent vitalism in contrast to the vitalism of Driesch which is called substantial vitalism. *See* EMERGENCE; EVOLUTION AND MIND.

See also C. D. Broad, *The Mind and its Place in Nature* (1923); C. Lloyd Morgan, *Emergent Evolution* (1926). (A. Wo.)

MECHITHARISTS, a congregation of Armenian monks in communion with the Church of Rome. The founder, Mechithar, was born at Sebaste in Armenia, 1676. He formally joined the Latin Church, and in 1701, with sixteen companions, he formed a definitely religious institute of which he became the superior. Their Uniat propaganda encountered the opposition of the Armenians and they were compelled to move to the Morea, at that time Venetian territory, and there built a monastery, 1706. On the outbreak of hostilities between the Turks and Venetians they migrated to Venice, and the island of St. Lazzaro was bestowed on them, 1717. This has since been the headquarters of the congregation, and here Mechithar died in 1749, leaving his institute firmly established. The Mechitharists are numbered among the lesser orders affiliated to the Benedictines.

BIBLIOGRAPHY.—See *Vita del servo di Dio Mechitar* (Venice, 1901); E. Boré, *Saint-Lazare* (1835); Max Heimbucher, *Orden u. Kongregationen* (1907) I. § 37; and the articles in Wetzer u. Welte, *Kirchenlexicon* (ed. 2) Herzog, *Realencyklopädie* (ed. 3), and the *Catholic Encyclopaedia*. (E. C. B.)

MECHNIKOV, ILYA (1845–1916), Russian biologist, was born at Ivanovka, in Kharkov on May 15, 1845. At the age of 17 he entered the Kharkov university and two years later went to Germany. Returning to Russia in 1867, he became a *dozent* in zoology both at St. Petersburg and at Odessa, where in 1870 he was made professor of zoology and comparative anatomy. In 1882 he went to Messina and there began his studies on the nature and habits of microbes. Henceforth he devoted himself to pathological study and in 1888 went to Pasteur in Paris, who gave him a laboratory in the École Normale. By 1892 his views on the essential importance of phagocytosis were firmly established. In that year he published *The Comparative Pathology of Inflammation,* followed in 1901 by his chief work, *Immunity in Infectious Diseases* (Eng. trs. 1905), and a more popular treatise, *The Nature of Man* (1903, Eng. trs. 1904). In later years he made a special study of the bacteria infesting the alimentary canal of man. In 1908 he was awarded the Nobel Prize for medicine. He died in Paris July 16, 1916.

See *Life* by his wife, Olga Mechnikov (1920 Eng. trans. 1921).

MECKLENBURG, a territory in northern Germany, on the Baltic sea, divided into the republics of Mecklenburg-Schwerin and Mecklenburg-Strelitz: these were reunited in Jan., 1934.

Mecklenburg-Schwerin is bounded N. by the Baltic sea, W. by Ratzeburg and Schleswig-Holstein, S. by Brandenburg and Hanover, and E. by Pomerania and Mecklenburg-Strelitz, and possesses three small exclaves. It became a republic in 1918 and by the constitution of 1920 it is governed by a Landtag of 64 members. The state sends one member to the Reichsrat of the German Republic. For administrative purposes it is divided into 17 divisions, in addition to the four cities of Rostock, Schwerin, Wismar (the capital) and Güstrow. Its area is 5,068 sq.m. Pop. (1933) 694,775, about 95% of whom are Protestant.

Mecklenburg-Strelitz consists of two detached parts, the former duchy of Strelitz on the East of Mecklenburg-Schwerin, and the former principality of Ratzeburg on the West. The first is bounded by Mecklenburg-Schwerin, Pomerania and Brandenburg, the second by Mecklenburg-Schwerin, Lauenburg, and the territory of the free town of Lübeck. Their joint area is 1,131 sq.m. Pop. (1933) 110,514. The state was declared a republic in 1918 and by the constitution of 1923 it is now governed by the 35 members of the Landtag who choose an executive of two. It is represented in the Reichsrat by one member. The capital is Neu-Strelitz.

Industries.—Mecklenburg lies wholly within the great North-European plain, and its flat surface is interrupted only by a low range of morainic hills, which form the watershed between the Baltic sea and the Elbe. Its highest point, the Helpter Berg, is 587 ft. above sea-level. The coast-line is for the most part covered with dunes. The rivers are numerous and some are navigable, and the facilities for inland water traffic are increased by canals. As a result of glaciation lakes are numerous (about 400). The temperature varies from a January average of 32° F to a July average of 64° F and the annual rainfall is about 23 in. Although there are long stretches of marshy moorland along the coast, the soil is on the whole productive, about half the area being cultivated, while one-fifth is forested. Agriculture is by far the most important industry, and the chief crops are rye, wheat, potatoes and hay. Smaller areas are devoted to maize, sugar beet, pease, rape, hemp, flax, hops and tobacco. The pastures support herds of sheep, cattle and horses. Red deer, wild swine and various other game are found in the forests. The industrial establishments include a few iron-foundries, wool-spinning mills, machine factories, dye-works, tanneries, brick-fields, soap-works, breweries, limekilns and tar-boiling works, tobacco factories and mills of various kinds. Rostock, Warnemünde and Wismar are the principal commercial centres. The chief exports are grain and other agricultural produce, live stock and wood; the chief imports are colonial produce, iron and coal. Fishing is carried on extensively in the numerous inland lakes.

The peasantry of Mecklenburg retain traces of their Slavonic origin, especially in speech, but their peculiarities have been much modified by amalgamation with German colonists. The townspeople and nobility are almost wholly of Saxon strain. The slowness of the increase in population is chiefly accounted for by emigration.

HISTORY

The Teutonic peoples, who in the time of Tacitus occupied the region now known as Mecklenburg, were succeeded in the 6th century by some Slavonic tribes, one of these being the Obotrites, whose chief fortress was Michilenburg, the modern Mecklenburg, near Wismar; hence the name of the country. Though partly subdued by Charlemagne towards the close of the 8th century, they soon regained their independence, and the effective subjugation of Mecklenburg was made by Henry the Lion, duke of Saxony. The Obotrite prince Niklot was killed in battle

in 1160 whilst resisting the Saxons, but his son Pribislaus (d. 1178) submitted to Henry the Lion, married his daughter to the son of the duke, embraced Christianity, and was permitted to retain his office. His descendants and successors, the later grand dukes of Mecklenburg, were the only ruling princes of Slavonic origin in Germany. In 1170 the emperor Frederick I. made Pribislaus a prince of the empire. In 1348 the emperor Charles IV. raised Mecklenburg to the rank of a duchy, and in 1418 the university of Rostock was founded.

In 1549 Lutheranism was recognized as the State religion; a little later the churches and schools were reformed and most of the monasteries were suppressed. In 1611, by a partition, Duke Adolphus Frederick I. (d. 1658) received Schwerin, and John Albert II. (d. 1636) received Güstrow. The town of Rostock, "with its university and high court of justice," was declared to be common property, while the diet or *landtag* also retained its joint character, its meetings being held alternately at Sternberg and at Malchin. In 1701, by the treaty of Hamburg, a new division of the country was made. Mecklenburg was divided into two parts, which were later represented by the duchies of Mecklenburg-Schwerin and Mecklenburg-Strelitz. At the same time the principle of primogeniture was again asserted, and the right of summoning the joint *landtag* was reserved to the ruler of Mecklenburg-Schwerin.

Under Duke Christian Louis of Mecklenburg-Schwerin there was signed, in April 1755, the convention of Rostock by which a new constitution was framed for the duchy. By this instrument all power was in the hands of the duke, the nobles, and the upper classes generally, the lower classes being entirely unrepresented. In the early years of the French revolutionary wars Duke Frederick Francis I. (1756–1837) remained neutral, but in 1806 his land was overrun by the French and in 1808 he joined the Confederation of the Rhine. He was the first member of the confederation to abandon Napoleon, to whose armies he had sent a contingent, and in 1813–14 he fought against France. In 1815 he joined the Germanic Confederation (Bund) and took the title of grand duke. In 1819 serfdom was abolished in his dominions. During the movement of 1848 the duchy witnessed a considerable agitation in favour of a more liberal constitution, but in the subsequent reaction all the concessions which had been made to the democracy were withdrawn and further restrictive measures were introduced in 1851 and 1852.

Mecklenburg-Strelitz adopted the constitution of the sister duchy by an act of Sept. 1755. Having been a member of the alliance against Napoleon, its duke, Charles, joined the Germanic Confederation in 1815 and assumed the title of grand duke.

In 1866 both the grand dukes of Mecklenburg joined the North German Confederation and in 1871 the two grand duchies became states of the German empire. The power of both grand ducal lines was ended by the German revolution of 1918.

See F. A. Rudloff, *Pragmatisches Handbuch der mecklenburgischen Geschichte* (Schwerin, 1780–1822); C. C. F. von Lützow, *Versuch einer pragmatischen Geschichte von Mecklenburg* (Berlin, 1827–35); *Jahrbücher des Vereins für mecklenburgische Geschichte und Altertumskunde* (Schwerin, 1836, fol.); C. Hegel, *Geschichte der mecklenburgischen Landstände bis 1555* (Rostock, 1856); *Mecklenburgisches Urkundenbuch* (Schwerin, 1873–1903); A. Mayer, *Geschichte des Grossherzogtums Mecklenburg-Strelitz 1816–1890* (New Strelitz, 1890); von Hirschfield, *Friedrich Franz II., Grossherzog von Mecklenburg-Schwerin und seine Vorgänger* (Leipzig, 1891); Volz, *Friedrich Franz II.* (Wismar, 1893); Bartold, *Friedrich Wilhelm, Grossherzog von Mecklenburg-Strelitz und Augusta Carolina* (New Strelitz, 1893); W. Raabe, *Mecklenburgische Vaterlandskunde* (Wismar, 1894–96); C. Schroder, *Friedrich Franz III.* (Schwerin, 1898); Tolzien, *Die Grossherzöge von Mecklenburg-Schwerin* (Wismar, 1904).

MECKLENBURG DECLARATION OF INDEPENDENCE, a document containing five resolutions embodying a declaration of independence from England, adopted, it is claimed, at a meeting on May 20, 1775, of the citizens of Mecklenburg county, North Carolina. The declaration was first printed in the *Raleigh Register* for April 30, 1819, from a draft written from memory in 1800 by John M. Alexander, recording clerk of the meeting. No contemporary draft has ever been discovered and the question of the document's authenticity has given rise to a large body of controversial literature. The best reasoned attack is W. H. Hoyt, *The Mecklenburg Declaration of Independence* (1907), and the best reasoned reply is J. H. Moore, *Defence of the Mecklenburg Declaration of Independence* (1908).

MEDALLION, in architecture and the decorative arts, any ornamental form with an oval or circular outline, differentiated from cartouche by the fact that its frame is extremely simple.

MEDALS AND COINS: *see* NUMISMATICS.

MEDEA, a famous sorceress, daughter of Aeetes, king of Colchis (Gr. Μήδεια). She fell in love with Jason the Argonaut, and exacted a terrible revenge for his faithlessness (*see* ARGONAUTS and JASON). After the murder of Jason's second wife and the death of her own children, she fled from Corinth in her car drawn by dragons, the gift of Helios, to Athens, where she married king Aegeus, by whom she had a son, Medus. But the discovery of an attempt on the life of Theseus, the son of Aegeus, forced her to leave Athens (Apollodorus i. 9, 28; Pausanias ii. 3, 6–11; Diod. Sic. iv. 45, 46, 54–56). Accompanied by her son she returned to Colchis, and restored her father to the throne, of which he had been deprived by his own brother Perses. Medus was regarded as the eponymous hero and progenitor of the Medes. Medea was honoured as a goddess at Corinth, and was said to have become the wife of Achilles in the Elysian fields. The chief seat of her cult, however, was Thessaly, which was always regarded as the home of magic. The popularity of the story of Jason and Medea in antiquity is shown by the large amount of literature on the subject. To name extant works only, she figures largely in Pindar (Fourth Pythian Ode), Euripides, Apollonius of Rhodes, Ovid (*Heroides* and *Metamorphoses*), Seneca (*Medea*), Valerius Flaccus and several prose authors; her story was already known to some at least of the Cyclic poets. She is also a common subject in ancient art. Beginning as a heroine of fairy-tales, she acquires a more human and also more formidable character especially in Euripides.

See the articles in Daremberg and Saglio's *Dictionnaire des antiquités* and Roscher's *Lexikon der Mythologie.*

MEDELLIN, a city of Colombia and capital of the department of Antioquia, 150 m. N.W. of Bogotá, on a plateau of the Central Cordillera, 4,823 ft. above sea-level. Pop. (1928) 120,044. Medellin, the foundation of which dates from 1674, stands in the valley of the Porce, a tributary of the Cauca, and is reputed to be one of the healthiest as well as one of the most attractive cities of the republic. It has a university, national college, school of mines and other educational institutions, assaying and refining laboratories, a public library and a mint. The principal industry of the surrounding country is mining, and gold and silver are exported in considerable quantities. Coffee and hides are also exported, but the trade of the city has been greatly impeded by difficulties of transportation. A railway now connects Medellin with Puerto Berrio on the Magdalena, but due to the high mountain of La Quiebra it is divided into two sections: that of Del Nus, that runs from Puerto Berrio to Limón; and that of Del Porce, from Santiago to Medellin. A tunnel is in project to unite the two sections, now joined by a motor road nine miles long.

MEDENINE, a small town in southern Tunisia, 46 m. S.E. of Gabès. The military camp is the most important French post on the frontier of Tripoli, and Medenine is the chief place of the southern territories of Tunisia. The Ksàr (a fortified village), consists of an agglomeration of *rhorfas*—long, low-vaulted chambers, piled one above the other four or five storeys high, and reached from the interior by steps, while on the external side they form a continuous defensive wall, pierced only by the small windows.

MEDFORD, a city of Middlesex county, Massachusetts, U.S.A., on the Mystic river, 5 m. N. by W. of Boston. It is served by the Boston and Maine railroad. The population was 39,038 in 1920 (22% foreign-born white), 47,627 in 1925 (state census), and was 59,714 in 1930 (by Federal census). The city occupies 8 sq.m., N. of Somerville, between Everett on the east and Arlington on the west. On its north-west border are the Mystic lakes, skirted by broad parkways of the Metropolitan Park system; and part of the Middlesex Fells reservation and most of the

Mystic River reservation fall within its limits. On "the hill," partly in Medford and partly in Somerville, is the 80 ac. campus of Tufts college (founded by Universalists in 1852), which has an endowment of about $7,500,000 and an enrollment of 2,194 in 1926–27, including 1,266 at the medical and dental schools conducted in Boston. Medford has some of the oldest and most interesting examples of domestic colonial architecture in New England, including the so-called "Cradock house" (1677–80), the "Wellington house" (1657), and the "Royall house," part of which is older than either of the others. The public library is housed in the reconstructed residence of Thatcher Magoun (famous as a shipbuilder from 1802), and the Medford Historical society occupies the house where Lydia Maria Child was born in 1802. The city is largely a residential suburb of Boston, but it has a number of manufacturing industries, with an output in 1925 valued at $7,014,465. The assessed valuation for 1928 was $75,518,500. The plantation of Mathew Cradock, first governor of the Massachusetts Bay Colony, covered a large part of the present area of Medford. In 1630 he sent out agents to settle his lands, and Governor Winthrop's "Ten Hills farm" (partly within the city's present limits) was occupied soon afterwards. The manufacture of brick and tile was an important industry in the 17th century; shipbuilding in the 18th and first half of the 19th; and the distilling of rum throughout the 18th and 19th. The last keel was laid in 1873 and the last distillery was discontinued in 1905. Many of the famous privateers of the War of 1812 were built here. Over the Cradock bridge across the Mystic (built in 1638) ran the principal thoroughfare from Boston to the north for 150 years. The course of Paul Revere's ride lay through Medford square, and within half an hour after he had passed the Medford minute men were on their way to Lexington and Concord. After the battle of Saratoga many of Burgoyne's officers were quartered here for the winter. The Middlesex canal was opened through Medford in 1803 and the first railroad in 1831. Medford was chartered as a city in 1892.

MEDFORD, a city of south-western Oregon, U.S.A.; the county seat of Jackson county and the metropolis of the Rogue river valley. It is on the Pacific highway; is a station on the Pacific coast air-mail route and has daily air passenger service to Portland and San Francisco; and is served by the Southern Pacific railroad, a logging railway and motor-coach lines. Pop. (1920) 5,756 (94% native white); in 1930 it was 11,007. The county has vast undeveloped natural resources, including 772,000 ac. of uncut timber and deposits of precious metals and many other minerals. About ⅛ of its total land area is under cultivation, of which 40,000 ac. are irrigated. Fruit-growing, lumbering, general agriculture, stock-raising and market-gardening are the principal industries. The region is famous for its pears, which brought a return of $4,000,000 for the season of 1927–28. Medford is a distributing point for these products, and has large fruit-packing and canning plants, cold-storage houses, a catsup factory, lumber and planing mills, flour and grist mills, creameries, iron works and machine shops. The assessed valuation of property in 1928 was $12,500,000. Crater Lake National Park is 80 m. N.E., and the city is headquarters for the park service and for the Crater National Forest service. Medford was founded in 1872, incorporated as a town in 1884 and as a city in 1905, and became the county seat in 1927.

MEDHURST, WALTER HENRY (1796–1857), English Congregationalist missionary to China, was born in London and educated at St. Paul's school. He was a missionary for the London Missionary Society at Shanghai from 1842 to 1856. He was a member of a committee of delegates for the revision of existing Chinese versions of the Bible. The result was a version in High Wen-li. With John Stronach he also translated the New Testament into the Mandarin dialect of Nanking. Medhurst died in London on Jan. 24, 1857.

MEDIA, the ancient name of the north-western part of Iran, the country of the Medes, corresponding to the modern provinces of Azerbaijan, Ardelan, Irak Ajemi, and parts of Kurdistan. It is separated from Armenia and the lowlands on the Tigris (Assyria) by the mighty ranges of the Zagrus (mountains of Kurdistan; in the northern parts probably called Choatras, Plin , v 98), and in the north by the valley of the Araxes (Aras). In the east it extends towards the Caspian sea; but the high chains of mountains which surround the Caspian sea (the Parachoathras of the ancients and the Elbrus) separate it from the coast, and the narrow plains on the border of the sea (Gilan, the country of the Gelae and Amardi, and Mazandaran, in ancient times inhabited by the Tapuri) cannot be reckoned as part of Media proper. The greater part of Media is a mountainous plateau, about 3,000–5,000ft. above the sea; but it contains some fertile plains. The climate is temperate, with cold winters, in strong contrast to the damp and unwholesome air of the shores of the Caspian, where the mountains are covered with a rich vegetation. Media contains only one river, which reaches the sea, the Sefid Rud (Amardus), which flows into the Caspian; but a great many streams are exhausted after a short course, and in the north-west is a large lake, the lake of Urumiah or Urmia.[1] From the mountains in the west spring some great tributaries of the Tigris, viz. the Diyala (Gyndes) and the Kerkheh (Choaspes). Towards the south-east Media passes into the great central desert of Iran, which, eastwards of Rhagae (mod. Rai, near Teheran), in the region of the "Caspian gates," reaches to the foot of the Elbrus chain. On a tract of about 150m. the western part of Iran is connected with the east (Khorasan, Parthyaea) only by a narrow district (Choarene and Comisene), where human dwellings and small villages can exist.

The people of the Mada, Medes (the Greek form Μῆδοι is Ionian for Μᾶδοι) appear in history first in 836 B.C., when the Assyrian conqueror Shalmaneser II. in his wars against the tribes of the Zagrus received the tribute of the Amadai (this form, with prosthetic *a-*, which occurs only here, has many analogies in the names of Iranian tribes). His successors undertook many expeditions against the Medes (Madai). Sargon in 715 B.C. subjected them "to the far mountain Bikni"; *i.e.,* the Elbrus (Demavend) and the borders of the desert, and received the tribute of 28, and in 713 of 46 chieftains; from their names we learn that they were an Iranian tribe and that they had already adopted the religion of Zoroaster. In spite of different attempts of some chieftains to shake off the Assyrian yoke, in connection with the northern barbarism, the Cimmerians and the Ashguza (perhaps the Scythians), who had invaded Armenia and Asia Minor, Media remained tributary to Assyria under Sargon's successors, Sennacherib, Esarhaddon and Assur-banipal.

Herodotus, i. 101, gives a list of six Median tribes (γένεα), among them the Paraetaceni, the inhabitants of the mountainous highland of Paraetacene, the district of Isfahan, and the Magi; *i.e.,* the Magians, the hereditary caste of the priests, who in Media took the place of the "fire-kindlers" (*athravan*) of the Zoroastrian religion, and who spread from Media to Persia and to the west. But the Iranian Medes were not the only inhabitants of the country. The names in the Assyrian inscriptions prove that the tribes in the Zagrus and the northern parts of Media were not Iranians nor Indo-Europeans, but an aboriginal population, like the early inhabitants of Armenia, perhaps connected with the numerous tribes of the Caucasus. We can see how the Iranian element gradually became dominant: princes with Iranian names occasionally occur as rulers of these tribes. But the Gelae, Tapuri, Cadusii, Amardi, Utii and other tribes in Northern Media and on the shores of the Caspian were not Iranians.

In the second half of the 7th century the Medians gained their independence and were united by a dynasty, which, if we may trust Herodotus, derived its origin from Deioces (*q.v.*) a Median chieftain in the Zagrus, who was, with his kinsmen, transported by Sargon to Hamath (Hamah) in Syria in 715 B.C. The origin and history of the Median Empire is quite obscure, as we possess only very scanty contemporary information, and not a single inscription from Media itself. Our principal source is Herodotus, who wrongly makes Deioces the first king and uniter of the whole nation, and dates their independence from *c.* 710—*i.e.* from the time when the Assyrian supremacy was at its height. But his account contains real historical elements, whereas the story which Ctesias gave (a list of nine kings, beginning with Arbaces, who is

[1]Anc. Mantiane, Strabo, xi. 529; Martiane, Ptol., vi. 2, 5.

said to have destroyed Nineveh about 880 B.C. preserved in Diod., ii. 32, seq. and copied by many later authors) has no historical value whatever, although some of his names may be derived from local traditions. According to Herodotus, Phraortes the son of Deioces was the first who attacked Nineveh, but was defeated and slain; and when his son Cyaxares renewed the attack, his progress was interrupted by an invasion of the Scythians, who founded an empire in western Asia, which lasted 28 years. This invasion of Asia by the Scythians appears to have greatly shaken the Assyrian empire; from Jeremiah and Zephaniah we know that a great invasion of Syria and Palestine by northern barbarians really took place in 626 B.C. Some stories in Herodotus show the Scythian warriors in connection with Cyaxares and the Medes: so the probable explanation is that the Babylonian annals generally give the title "King of the hosts of the Manda" to the Median kings; Manda is an old word for the nomadic tribes of the north, which is also applied to the Cimmerian chieftains.

Until 1923 we knew practically nothing about the fall of the Assyrian empire. But in this year, a chronicle was discovered by Gadd (the "Fall of Nineveh") in the British Museum, which gives us the exact dates. From it we learn that Nabopolassar of Babylon and Cyaxares (Uvakishtar) of Media began the war against the Assyrians (who were supported by the Egyptians) in 616 B.C. In 612 the allies began the siege of Nineveh, which was stormed and destroyed. The last king, Siusharishkun, the Saracus of Berossus probably sought his death in the flames of his palace; but an offspring of this dynasty, Ashuruballit, still maintained the fragments of his kingdom for some years in Harran (Carrhae), until this town also was taken by the Medes.

The victors divided the provinces between themselves. Syria with Palestine and the south of Mesopotamia fell to the Chaldaean empire of Babylon; the Median king ruled over the greatest part of Iran, Assyria and northern Mesopotamia, Armenia and Cappadocia. His power was very dangerous to their neighbours, and the exiled Jews expected the destruction of Babylonia by the Medes (Isa. xiii., xiv., xxi.; Jerem. l. li.), and Nebuchadrezzar tried to secure his kingdom by great fortifications, canals and walls against the menace from the north. He succeeded in establishing a state of equilibrium for half a century, further secured by an intermarriage between the dynasties. When Cyaxares attacked Lydia, the kings of Cilicia and Babylon intervened and negotiated a peace in 585, by which the Halys was established as the boundary.

About the internal organization of the Median Empire we know only that the Greeks derive a great part of the ceremonial of the Persian court, the costume of the king, etc., from Media. But it is certain that the national union of the Median clans was the work of their kings; and probably the capital Ecbatana (*q.v.*) was created by them.

By the rebellion of Cyrus, king of Persia, against his suzerain Astyages, the son of Cyaxares, in 553, and his victory in 550, the Medes were subjected to the Persians. In the new empire they retained a prominent position; in honour and war they stood next to the Persians; the ceremonial of their court was adopted by the new sovereigns who in the summer months resided in Ecbatana, and many noble Medes were employed as officials, satraps and generals. After the assassination of the usurper Smerdis, a Mede Fravartish (Phraortes), who pretended to be of the race of Cyaxares, tried to restore the Median kingdom, but was defeated by the Persian generals and executed in Ecbatana (Darius in the Behistun inscr.). Another rebellion, in 409, against Darius II. (Xenophon, *Hellen.*, i. 2, 19) was of short duration. But the non-Aryan tribes of the north, especially the Cadusians, were always troublesome; many abortive expeditions of the later kings against them are mentioned.

Under the Persian rule the country was divided into two satrapies. The south, with Ecbatana and Rhagae (Rai), Media proper, or "Great Media," as it is often called, formed in Darius' organization the eleventh satrapy (Herodotus, iii. 92), together with the Paricanians and Orthocorybantians; the north, the district of Matiane (*see* above), together with the mountainous districts of the Zagros, and Assyria proper (east of the Tigris) was united with the Alarodians and Saspirians in eastern Armenia, and formed the 18th satrapy (Herod., iii. 94; cf. v. 49, 52, vii. 72). When the empire decayed and the Carduchi and other mountainous tribes made themselves independent, eastern Armenia became a special satrapy, while Assyria seems to have been united with Media: therefore Xenophon in the *Anabasis*, ii. 4, 27; iii. 5, 15; vii. 8. 25; cf. iii. 4. 8 sqq. always designates Assyria by the name of Media.

Alexander occupied Media in the summer of 330; in 328 he appointed as satrap Atropates, a former general of Darius (Arrian. iii. 8, 4, iv. 18, 3, vi. 29, 3), whose daughter was married to Perdiccas in 324 (Arrian, vii. 4, 5). In the partition of his empire southern Media was given to the Macedonian Peithon; but the north, which lay far off and was of little importance for the generals who fought for the inheritance of Alexander, was left to Atropates. While southern Media with Ecbatana passed to the rule of Antigonus, and afterwards (about 310) to Seleucus I., Atropates maintained himself in his satrapy and succeeded in founding an independent kingdom. Thus the partition of the country, which the Persian had introduced, became lasting; the north was named Atropatene after the founder of the dynasty, a name which is preserved in the modern Azerbaijan. The capital was Gazaca in the central plain, and the strong castle Phraaspa (Dio Cass., xlix. 26; Plut., *Anton.*, 38; Ptol., vi. 2, 10) or Vera (Strabo, xi. 523), probably identical with the great ruin Takhti Suleiman, with remains of Sassanid fire-altars and of a later palace. The kings had a strong and warlike army, especially cavalry (Polyb., v. 55; Strabo, xi. 253). Nevertheless, King Artabazanes was forced by Antiochus the Great in 220 to conclude a disadvantageous treaty (Polyb., v. 55), and in later times the rulers became in turn dependent on the Parthians, on Tigranes of Armenia and then Rome. Pompey defeated their King Darius (Appian, *Mithr.* 108), Antonius invaded Atropatene,—Augustus received the homage of their kings. In the time of Strabo (A.D. 17), the dynasty existed still (p. 523); in later times the country seems to have become a Parthian province.

Southern Media remained a province of the Seleucid empire for a century and a half, and Hellenism was introduced everywhere. "Media is surrounded everywhere by Greek towns, in pursuance of the plan of Alexander, which protect it against the neighbouring barbarians," says Polybius (x. 27). Only Ecbatana retained its old character. But Rhagae became a Greek town, Europus; and with it Strabo (xi. 524) names Laodicea, Apamea, Heraclea or Achais (*cf.* Plin., vi. 48). Most of them were founded by Seleucus I. and his son Antiochus I. In 221, the satrap Molon tried to make himself independent (there exist bronze coins with his name and the royal title), together with his brother Alexander, satrap of Persis, but they were defeated and killed by Antiochus the Great. In the same way, in 161, the Median satrap Timarchus took the diadem and conquered Babylonia; on his coins he calls himself "the great King Timarchus"; but this time again the legitimate king, Demetrius I., succeeded in subduing the rebellion, and Timarchus was slain. But with Demetrius I. the dissolution of the Seleucid empire begins, which was brought on chiefly by the intrigues of the Romans, and shortly afterwards, about 150, the Parthian king, Mithridates I. (*q.v.*), conquered Media (Justin, xli. 6). From this time Media remained subject to the Arsacids, who changed the name of Rhagae, or Europus, into Arsacia (Strabo, xi. 524), and divided the country into five small provinces (Isidorus Charac.). From the Arsacids or Parthians, it passed in A.D. 226 to the Sassanids, together with Atropatene. By this time the old tribes of Aryan Iran had lost their character and had been amalgamated into the one nation of the Iranians. The revival of Zoroastrianism, which was enforced everywhere by the Sassanids, completed this development. It was only then that Atropatene became a principal seat of fire-worship, with many fire-altars. Rhagae now became the most sacred city of the empire and the seat of the head of the Zoroastrian hierarchy; the Sassanid *Avesta* and the tradition of the Parsees therefore consider Rhagae as the home of the family of the Prophet. Henceforth the name of Media is used only as a geographical term and begins to disappear from the living language; in Persian traditions

it occurs under the modern form *Māh* (Armen. *Mai;* in Syriac the old name *Madai* is preserved; *cf.* Marquart, *Eranshahr,* 18, *seq.*).

For Mohammedan history *see* CALIPHATE; for later history SELJUKS and PERSIA. (ED. M.)

MEDIA, a borough of Pennsylvania, U.S.A., county seat of Delaware county, 8 m. W. of Philadelphia, on the Pennsylvania railway and Federal highway 1. It has a municipal airport. Pop. (1920) 4,109 (80% native white); and 5,372 in 1930. Media was founded by the Friends in 1682 There is still a large Quaker element in the population. The borough was incorporated in 1850.

MEDIAN, the point on a statistical scale of the distribution of cases, above which and below which lie exactly 50% of the cases. The median is thus a measure of "central tendency." It has the advantage over the arithmetical mean or "average" that it is not affected by unusually high or low values of the variable. For instance, given the values 3, 4, 5, 6, 7, 8, 100, the median is 6, and the arithmetic mean is 19. For some purposes the median value better describes the central tendency of such a series.

In a triangle, a line drawn from any vertex to the mid-point of the opposite side. The three medians of a triangle meet in a point which is two-thirds of the distance from each vertex to the mid-point of the opposite side. This point is the *centroid* of the triangle, and is its centre of gravity.

MEDIANT, a term in music signifying the note occupying the third degree of the diatonic scale (*e.g.,* E in the key of C), the name being derived from the fact that the note in question stands mid-way between the tonic (the first note) and the dominant (the fifth). (*See* HARMONY.)

MEDIATION, in international law the intervention of a third Power, on the invitation or with the consent of two other Powers, for the purpose of arranging differences before an appeal to arms or after war has broken out. In either case the mediating Power negotiates on behalf of the parties who invoke or accept its aid, but does not go further. Unlike an arbitrating Power the mediator limits his intervention to suggestion and advice. His action is liable to be arrested at any time at the will of either party unless otherwise agreed, in which case to arrest it prematurely would be a breach of good faith.

Of successful mediation in the strict sense there have been many instances: that of Great Britain, in 1825, between Portugal and Brazil; of France, in 1849–50, when differences arose between Great Britain and Greece; of the Great Powers, in 1868–69, when the relations of Greece and Turkey were strained to breaking-point by reason of the insurrection in Crete; of Pope Leo XIII., in 1885, between Germany and Spain in the matter of the Caroline islands. In these cases mediation averted war. The Austro-Prussian War of 1866, the war between Chile and Peru in 1882, that between Greece and Turkey in 1897, and that between Russia and Japan in 1905 are instances of wars brought to a close through the mediation of neutral Powers. Mediation has also been occasionally employed where differences have arisen as to the interpretation of treaties or as to the mode in which they ought to be carried out; as when Great Britain mediated between France and the United States with regard to the Treaty of Paris of July 4, 1830. In one case at least mediation has been successful after a proposal for arbitration had failed. In 1844, when war between Spain and Morocco was threatened by reason of the frequent raids by the inhabitants of the Rif on the Spanish settlement of Ceuta, Spain declined arbitration on the ground that her rights were too clear for argument. But both she and Morocco subsequently accepted joint mediation at the hands of Great Britain and France.

The cause of mediation was considerably advanced by the Declaration of Paris of 1856. The plenipotentiaries of Great Britain, France, Austria, Russia, Sardinia and Turkey recorded in a protocol, at the instance of Lord Clarendon, their joint wish that "States between which any misunderstanding might arise should, before appealing to arms, have recourse so far as circumstances might allow (*en tant que les circonstances l'admettraient*) to the good offices of a friendly Power." Article 8 of the Treaty of Paris, concluded in the same year, stipulated that "if there should arise between the Sublime Porte and one or more of the other signing Powers any misunderstanding which might endanger the maintenance of their relations, the Porte and each of such Powers, before having recourse to the use of force, shall afford the other contracting parties the opportunity of preventing such an extremity by means of mediation." These precedents (in which it will be seen that "good offices" and "mediation" are used interchangeably) were followed in the general act agreed to at the Conference held at Berlin in 1884–85, the object of which was to secure religious and commercial liberty and to limit warlike operations in the Congo basin.

A special form of mediation was adopted by The Hague Peace Conferences of 1899 and 1907. It was provided that, before an appeal to arms or during hostilities, a Power not a party to the dispute shall be entitled to offer good offices or mediation to the States at variance, and that the exercise of this right shall not be regarded by either of the parties in dispute as an unfriendly act. (M. H. C.; H. H. L. B.)

MEDIATIZATION, the process by which at the beginning of the 19th century, a number of German princes, hitherto sovereign as holding *immediately* of the emperor, were deprived of their sovereignty and *mediatized* by being placed under that of other sovereigns.

See August Wilhelm Heffter *Die Sonderrechte der Souveränen und der Mediatisirten, vormals reichsständischen Häuser Deutschlands* (1871).

MEDICAL AND SURGICAL SOCIETIES. The first meeting of the *Congrès Médical International* was held at Paris in 1867; a *Bulletin* has been issued annually since 1868, and the first Surgical Congress was held in Paris in 1885. The first *Congrès Périodique Internat. d'Ophthalmologie* took place at Brussels in 1857. The Royal Colleges of Physicians and of Surgeons of London, Edinburgh and Dublin do not come within our scope The *Medical Society of London* (1773) is the oldest in the metropolis; it has issued *Memoirs* (1787–1805), *Transactions* (1810, etc.), and *Proceedings* (1872, etc.). The *Royal Society of Medicine* was formed, by Royal charter, in 1907 by the amalgamation of the following societies: *Roy. Med. and Chir. Soc.* (1805), *Pathological Soc.* (1846), *Epidemiological Soc.* (1850), *Odontol. Soc. of Gt. Britain* (1856), *Obstetrical Soc.* (1858), *Clinical Soc.* (1867), *Dermatological Soc. of London* (1882), *British Gynaecological Soc.* (1884), *Neurolog. Soc.* (1886), *British Laryngol. Rhinol. and Otological Assoc.* (1888), *Laryngol. Soc.* (1893), *Soc. of Anaesthetists* (1893), *Dermatol. Soc. of Gt. Brit. and Ireland* (1894), *Otological Soc.* (1899), *Soc. for Study of Diseases in Children* (1900), *British Electro-therapeutic Soc.* (1901) and the *Therapeutical Soc.* (1902). Most of these societies had separate *Transactions* or *Proceedings* which are now incorporated in the *Proc. Roy. Soc. Med.* Other British or London societies (past and present) include the *Abernethian Society* (1795), which issues *Proceedings; Anatomical Soc. of Gt. Brit. and Ireland* (1887); *British Dental Association* (1880), with a *Journal* (1880, etc.); *British Homoeopathic Association* (1859), with *Annals* (1860, etc.); *British Medical Association* (1832), which has more than forty home and colonial branches, and publishes *British Medical Journal* (1857, etc.); *Hahnemann Publishing Society* (1852), *Materia Medica* (1852, etc.); *Harveian Society* (1831); *Hunterian Society* (1819), *Trans.; Lister Institute* (incorp. 1891); *Medico-Legal Soc. of London, Trans.; Medico-Psycholog. Assn. of Gt. Britain and Ireland* (1841, incorp. 1895); *New Sydenham Society* (1858), which published *Biennial Retrospect* (1867, etc.), and translations and reprints of books and papers of value, succeeded the old *Sydenham Society* (1844–1858), which issued 40 vols.; *Ophthalmological Society* (1880), *Trans.; Pathological Society of Gt. Brit. and Ireland, Jour. of Pathology and Bacteriology; Pharmaceutical Society* (1841), with museum, *Pharmaceutical Journal* (1842, etc.); *Physiological Association* (1876), *Journ. of Physiology* (1878, etc.); *Brit. Psycholog. Soc., Brit. Jn. Med. Psychol.; Soc. for Study of Inebriety* (1884), *Brit. Jn. of Inebriety; Med. Off. Health Assn.* (1884), *Jn. of School Hygiene; Roy. Med. Psychol. Assn.* (1926), *Jn. of Mental*

Sci.; Roy. Soc. of Med. and Hyg., Trans.; Assn. Physicians Gt. Brit. and Ireland, Quarterly Jn. Med.; Rontgen Soc. now merged into the Institute of Radiology, *Journal; Royal Institute of Public Health* (1886, incorp. 1892), *Journ. Royal Sanitary Institute* (1876, incorp. 1888), the council of which appoints examiners, directs Parkes Museum, founded in 1876 in memory of Dr. E. A. Parkes; *Society of Medical Officers of Health* (1856), *Trans.* and *Public Health; Soc. of Public Analysts, Analyst.* The provincial societies are very numerous and include: Bradford, *Med. Chir. Soc.* (1863); Bristol, *Med. Chir. Soc.;* Cardiff, *Med. Soc.* (1870); Liverpool *Sch. of Tropical Med.* (1898, incorp. 1905), *Memoirs;* Manchester, *Med. Soc.* (1848); Newcastle-upon-Tyne, *North. and Durham Med. Soc.* (1848). Dublin, *Roy. Acad. of Med. in Ireland* (1882), *Trans.* (1883, etc.); *Pharmac. Soc. of Ireland* (1875). Edinburgh, *Roy. Med. Soc.* (1737; charter 1778); *Harveian Soc.* (1752); *Medico-Chirurg. Soc.* (1821), *Trans.* (1824, etc.); and *Obstetrical Soc.* (1840). Aberdeen, *Med. Chir. Soc.* (1789). Glasgow, *Medico-Chirurg. Soc.* (1866), based upon *Med. Soc.* and *Med.-Chirurg. Soc.* (both 1814), joined by *Path. Soc.* in 1907.

AUSTRALIA: Melbourne, *Med. Soc. of Victoria, Austr. Med. Journ.* (1856, etc.). CANADA: Montreal, *Union Méd. du Canada, Revue* (1872, etc.); *Canada Med. Assoc., Trans.* (1877, etc.). INDIA: Bombay, *Med. and Physical Soc., Trans.* (1838, etc.). Calcutta, *Med. Soc., Trans.* (1883, etc.).

UNITED STATES: *Amer. Pub. Health Assoc., Reports* (1873, etc.); *Amer. Dental Assoc., Trans.* (1860, etc.); and *Amer. Inst. of Homoeop., Trans.* (1878, etc.). The headquarters of the *American Medical Association* (1847) are at Chicago; it publishes a *Journal*. The *American Surgical Association* (1880) unites at Washington every third year with the *Congress of American Physicians and Surgeons*. The State medical associations include those of Alabama, *Trans.* (1869, etc.); Georgia, *Trans.* (1873, etc.); Maine, *Trans.* (1853, etc.); Missouri, *Trans.* (1851, etc.); and South Carolina, *Trans.* The State medical societies include those of Arkansas, *Trans.* (1877, etc.); California, *Trans.* (1870, etc.); Illinois, *Trans.* (1851, etc.); Kansas, *Trans.* (1867, etc.); Michigan, *Trans.* (1869, etc.); Minnesota, *Trans.* (1874, etc.); Nebraska, *Trans.* (1869, etc.); New Jersey, *Trans.* (1859, etc.); Pennsylvania, *Trans.* (1851, etc.); Rhode Island, *Trans.* (1877, etc.); Texas, *Trans.* (1874); and Wisconsin, *Trans.* (1880, etc.). To these have to be added the following town associations. Albany, *Med. Soc., Journal* (1807, etc.). Baltimore, *Med. and Chirurg. Faculty of Maryland, Trans.* (1856, etc.). Boston, *Amer. Gynaecolog. Soc., Trans.* (1876, etc.); *Mass. Medico-Legal Soc., Trans.* (1878, etc.). Denver, *Acad. of Med.* (1903). New York, *Acad. of Med., Trans.* (1847, etc.) and *Bull.* (1860, etc.); *Med. Soc., Trans.* (1815, etc.); *Medico-Chirurg. Soc., Trans.* (1878, etc.); *Amer. Surg. Assoc., Trans.* (1883, etc.); *Medico-Legal Soc., Sanitarian* (1873, etc.); *Amer. Ophthalmolog. Soc., Trans.* (1865, etc.); *Path. Soc.* (1844), *Trans.* (1875–1879), *Proc.* (1888, etc.). Philadelphia, *Med. Soc., Trans.* (1850, etc.); *Obstet. Soc., Trans.* (1869, etc.); *Amer. Pharm. Assoc., Proc.; Patholog. Soc.* (1857), *Trans.* (1897, etc.); *Coll. of Physicians* (1787); *Amer. Soc. of Tropical Med.* (1903). Richmond, *Med. Soc., Trans.* (1871, etc.).

FRANCE: Besançon, *Soc. de Méd.* (1845), *Bull.* (1845, etc.). Bordeaux, *Soc. de Méd.* (1798), *Journ.* (1829, etc.); *Soc. de Pharm.* (1834), *Bull.* (1860, etc.); *Soc. de Méd. et de Chirurg.; Soc. d'Anat. et de Physiol.* (1879), *Bull.* (1880). Caen, *Soc. de Méd.* (1799; known by its present name since 1875), *Journal* (1829), *Mém.* (1869). Chambéry, *Soc. de Méd.* (1848), *Comptes rend.* (1848, etc.) and *Bull.* (1859, etc.). Grenoble, *Soc. de Méd.* Havre, *Soc. de Pharm.* (1858), *Mém.* Lille, *Soc. de Méd.* (1843), *Bull.* (1845, etc.), Lyons, *Soc. Nat. de Méd.* (1789), *Le Lyon méd.* (1869, etc.). Marseilles, *Soc. de Méd.* (1800), *Comptes rend.* (1826–1853) and *Le Mars. méd.* (1869, etc.); *Soc. Méd.-Chirurg.* (1872). Paris, *Soc. de Méd. Pratique* (1808), *Bull.; Acad. Nat. de Méd.* (1820); *Soc. Nat. de Chirurg.* (1843, reorganized 1859), *Mém.* (1847, etc.) and *Bull.* (1851, etc.); *Soc. Anat.* (1803), *Bull.* (1826, etc.); *Soc. Clinique, Bull.* (1877, etc.); *Soc. Méd. des Hôpitaux, Bull.* (1849, etc.); *Soc. Méd. Légale; Soc. de Pharm.* (1803), *Journ.* (1815, etc.); *Soc. de Thérapeutique; Soc. Fran. de Hygiène; Soc. Centr. de Méd. Vétérinaire* (1844), *Bull.; Assoc. Int. de l'Inst. Marey* (1898) (for examining physiological methods and apparatus), *Bull., Travaux.* Rouen, *Soc. de Méd.* (1821), *Union Méd.* (1861, etc.); *Soc. Libre des Pharmaciens* (1802), *Bull.* Strasbourg, *Soc. de Méd.* (1842), *Mém.* (1850, etc.); *Soc. Vétérin.* (1864); *Medizinisch.-Naturwissenschaftlicher Ver.* (1873). Toulouse, *Soc. de Méd.* (1801), *Bull.* and *Revue* (1867, etc.). Tours, *Soc. Méd.* (1801). GERMANY and AUSTRIA-HUNGARY: *Deutscher Ärztevereinsbund* (1872), *Verhandl.; Central Ver. d. Zahnärzte* (1859), *Mittheil.; D. Veterinärrath* (1874); *D. Apotheker-Ver.* (1820), *Archiv* (1822, etc.). Berlin, *Ver. f. Heilkunde* (1832), *Magazin* (1835, etc.); *Ges. f. Geburtshülfe u. Gynaekologie* (1876), *Ztschr.* (1877, etc.); *Ges. f. Heilkunde* (1855); *Berl. Med. Ges.* (1860), *Verhandl.* (1865, etc.); *Physiolog. Ges.* (1875), *Verhandl.* (1877, etc.); *D. Ver. f. Med. Statistik* (1868); *Ver. Homöop. Ärzte* (1871), *Ztschr.* (1882, etc.); *D. Ges. f. Chirurgie* (1872), *Verhandl.* Bonn, *Verband der Ärztl. Vereine* (1865). Breslau, *Ver. f. Physiolog. Heilkunde* (1848), *Ztschr.* (1850, etc.); *Verband d. Schles. Ärzte-Ver.* (1878). Cologne, *Rhein. Med.-Chirurg. Ver.* (1848), *Organ* (1852, etc.). Darmstadt, *Ärztl. Kreisver.* (1844). Dresden, *Ges. f. Natur- u. Heil-Kunde* (1818), *Jahresber.* (1848, etc.). Erlangen, *Physik.-Med. Soc.* (1808), *Sitzungsber.* (1870, etc.). Frankfort, *Arztl. Ver.* (1845), *Jahresber.* (1857, etc.). Hamburg, *Arztl. Ver.* (1816); *Deutsche Ges. für Gesch. der Medizin* (1901), *Mitteil.* Hanover, *Ver. Analyt. Chemiker* (1878). Heidelberg, *Ophthal. Ges.* (1857). Jena, *Med.-naturwissenschaftliche Ges.* (1854), *Zeitschr.* (1874, etc.). Königsberg, *Ver. f. wiss. Heilkunde* (1851). Leipzig, *Med. Ges.* (1829); *Ges. f. Geburtschülfe* (1854), *Mittheil.; Homöop. Central-Ver.* (1829); Magdeburg, *D. Chirurgen-Ver.* (1844), *Ztschr.* (1847, etc.). Munich, *Ärztl. Ver.* (1833), *Int.-Blatt* (1854, etc.). Stuttgart, *Württemb. Ärztl. Ver.* (1831), *Corr.-Blatt* (1832, etc.); *Hahnemannia* (1868), *Mittheil.* (1873, etc.); *Apotheker-Ver.* (1822), *Pharm. Wochenblatt* (1861, etc.). Vienna, *Ges. der Ärzte, Ztschr.* (1844, etc., etc.); *Ges. für innere Medizin u. Kinderheilkunde, Med. Wochenschrift.* Weimar, *Med.-naturwiss. Ver.* (1863). Würzburg, *Physikal.-med. Ges.* (1849), *Verhandl.* (1850, etc.). SWITZERLAND: Geneva, *Soc. Méd.* Zürich, *Soc. de Méd.; Schweiz. Apotheker-Ver.* ITALY: Bologna, *Soc. Med.-chirurg.* Genoa, *Accad. Med.-chirurg.* Milan, *Soc. Ital. d' Igiena.* Modena, *Soc. Med.-chirurg.* Naples, *Real Accad. Med.-chirurg.* Palermo, *R. Accad. delle Sc. Med.* (1649), *Atti* (1889, etc.). Rome, *R. Istit. Fisico-patologico.* Turin, *Accad. Real Med.-chirurg.* BELGIUM: Antwerp, *Soc. de Méd.* (1839), *Annales.* Brussels, *Acad. Roy. de Méd.* (1841), *Bull.* (1841, etc.) and *Mém.* (1843, etc.); *Soc. Roy. de Pharm.* (1845), *Bull.; Soc. d' Anat. Patholog.* (1846), *Annales; Soc. Belge de Méd. Homoeop.; Soc. Roy. des Sc. Méd. et Nat.* (1822), *Journal* (1842, etc.), *Annales* (1892, etc.), *Bulletin* (1843, etc.); *Inst. Solvay de Physiol.* (1894), with electro-physiological, chemical, embryological and other laboratories, and lecture hall. Ghent, *Soc. de Méd.* (1834), *Annales.* Liége, *Soc. Méd.-chirurg.* HOLLAND: Amsterdam, *Genootschap ter Bevordering der Genees- en Heel-Kunde, Verhandel.* (1841, etc.); *Nederl. Maatschappij ter Bevord. der Pharmacie.* Batavia (Java), *Geneeskundige Vereeniging.* DENMARK: Copenhagen, *K. Med. Selskab; Veterinaer Selskab.* NORWAY: Oslo, *Med. Selskab, Magazin* (1840, etc.). SWEDEN: Stockholm, *Farmaceutiska Inst.; Svenska Läkaresällskapet* (1808), *Handl.* (1813, etc.). Upsala, *Läkareförenig, Förhandl.* (1865, etc.). SPAIN: Madrid, *R. Acad. Med.* (1732). PORTUGAL: Lisbon, *Soc. de Sc. Med.* (1835), *Jornal* (1835, etc.); *Soc. Pharm. Lusitana.* RUSSIA: Moscow, *Phys.-med. Soc.* Leningrad, *Soc. of Practical Physicians; Imp. Pharm. Soc.* Tomsk (Siberia), *Soc. of Naturalists and Physicians* (1889), *Protocol.* RUMANIA: Jassy, *Soc. of Naturalists and Physicians* (1830), *Buletinul.* ESTONIA: Tartu, *Pharm. Soc.* FINLAND: Helsingfors, *Finska Läkaresällskapet* (1835), *Handl.* (1841). LATVIA: Riga, *Soc. of Prac. Phys.* POLAND: Wilno, *Imp. Med. Soc.* (1805). Warsaw, *Med.-Chirurg. Soc.* GREECE: Athens, *Soc. Méd.* TURKEY: Constantinople, *Soc. Imp. de Méd.; Soc. de Pharm.* CENTRAL and S. AMERICA: Buenos Aires, *Asoc. Med.* Caracas, *Escuela Med.* Guadalajara (Mexico), *Soc. Med.* Merida (Mex.), *Soc. Med.* Mexico, *Acad. de Med.; Soc. Med.* Monte Video, *Soc. de Med.* Rio de Janeiro, *Instituto*

Oswaldo Cruz, formerly *Instituto de Manguinhos* (for the promotion of experimental pathology); *Soc. Med. e Cirurgia*, Santiago, *Soc. Med.* JAPAN: Tokyo, *Soc. for Adv. of Med. Sc., Trans.* (1885, etc.).

New York Academy of Medicine.—This is an American association which was founded in 1847 to advance medical education, to aid the scientific development of its members and to make progress in all matters relating to public health. It has (1928) 1,690 fellows and 38 honorary fellows. The library is one of the largest in the United States and contains 150,256 volumes, 104,564 octavo pamphlets, 9,720 quarto pamphlets and subscribes to 1,570 current serials. It is open to the public daily as well as to its fellows (except Dec. 25 and July 4). The Bureau of Clinical Information, maintained by the Committee on Medical Education, offers detailed information regarding all medical activities in New York and other cities of the United States, Canada and in European centres. The Committee on Public Health Relations gathers and publishes pertinent information with regard to health activities of the municipal and voluntary social service agencies. The stated meetings of the academy and those of its various sections are open to physicians and medical students as well as to its fellows.

MEDICAL ARTICLES. Under the general subject of Medicine several subdivisions are included, viz., Anatomy, Pharmacology and Therapeutics, Pathology, Midwifery and Diseases of Women, Surgery, Medicine, Public Health, Tropical Medicine, Veterinary Medicine. In each instance a general article is given in which the scope of the subject is presented, but in addition so many special articles are included that they must be indicated in separate paragraphs.

Anatomical Articles.—In a general article on ANATOMY the subject is reviewed particularly from the superficial and artistic points of view and also in respect of the modifications introduced by X-ray examination during recent years. In addition to numerous smaller articles which are included on special subjects, the ALIMENTARY CANAL, ARTERIES, BRAIN, CONNECTIVE TISSUES, DUCTLESS GLANDS, EAR, EYE, HEART, JOINTS, LIVER, LYMPHATIC SYSTEM, MUSCULAR SYSTEM, NERVE, NERVOUS SYSTEM. REPRODUCTIVE SYSTEM, RESPIRATORY SYSTEM, SKELETON, SKIN AND EXOSKELETON, SKULL, SPINAL CORD. TEETH, URINARY SYSTEM and VEINS receive extended notice. Numerous illustrations are included and though the subjects are treated primarily from the human point of view subsections deal with the comparative anatomical and embryological aspects. Adequate bibliographies are given at the end of most of the articles.

Bacteriological Articles.—The main subject is treated under the headings of BACTERIA AND DISEASE, and in the articles on Bacteriology: FILTER PASSING VIRUSES, IMMUNITY, PHAGOCYTOSIS, SERUM THERAPY, VACCINE THERAPY. In addition all diseases of known or suspected dependence upon bacterial infection, *e.g.*, diphtheria, measles, food poisoning, carry some reference to the bacterial factor inculpated. In INFLAMMATION AND ITS SEQUELS a broad survey is given of the response of the body to bacterial and non-bacterial irritants and the points of similarity and of difference are contrasted. Closely akin to this group is that on PARASITIC DISEASES in which are described the characters and effects of various naked-eye and microscopic animal parasites affecting man and lower animals. An adequate bibliography is placed at the end of each article.

Pharmacological Articles.—General articles are those on PHARMACY, PHARMACOLOGY and PHARMACOPOEIA. In addition to shorter notices on the great majority of drugs found in the most important pharmacopoeias there are special articles of greater length on ANAESTHESIA AND ANAESTHETICS; ANTISEPTICS AND ASEPSIS; BALNEOTHERAPEUTICS; ELECTROTHERAPY; POISON; RADIOTHERAPY; RADIUMTHERAPY and SUNLIGHT TREATMENT. Important drugs like CALABAR BEAN; DIGITALIS; BELLA-DONNA; CINCHONA BARK, ALKALOIDS OF; OPIUM and the BARBITURIC ACID and SULPHONAL Group receive greater notice. The general principle is to indicate the botanical origin of a drug with a description of the special plant or its varieties from which the drug is obtained and this is followed by its chemistry so far as is known, its pharmacological action and its uses. In many instances a bibliography of recent work on the particular subject is appended.

Pathological Articles.—Some indication of the known or suspected pathology is given in the case of all diseases, but special articles of a pathological kind are contained in PATHOLOGY; ANAPHYLAXIS; ATROPHY; HYPERTROPHY; BLOOD TRANSFUSION; CANCER RESEARCH; HAEMORRHAGE; INFLAMMATION AND ITS SEQUELS; MONSTER; NEUROPATHOLOGY; PAIN, SIGNIFICANCE OF; SHOCK AND COLLAPSE; TUMOUR. In this connection a knowledge of the normal appearances is necessary and reference must be made to the various anatomical articles (*see* ANATOMICAL ARTICLES) as well as to those which deal with EPITHELIUM; ENDOTHELIUM; CONNECTIVE TISSUES; MUSCLE, STRUCTURE OF; GLANDS; etc. Shorter articles deal with ABSCESS; ALCOHOL, PATHOLOGICAL EFFECTS OF; ANKYLOSIS; AUTOPSY; BED-SORE; BLISTER; BUNION; CALCULI (with colour plate); CARBUNCLE; CORN; DILATATION; EMPYEMA; FROSTBITE; NAEVUS; NECROSIS; GANGRENE; ULCER; etc.

Midwifery and Diseases of Women.—The chief articles in this subsection are ABORTION; BIRTH CONTROL; EMBRYO; GYNAECOLOGY; MENSTRUATION; OBSTETRICS; PLACENTA; PUERPERAL FEVER. Shorter articles are on CAESAREAN SECTION; MENOPAUSE; OVARIOTOMY; TWILIGHT SLEEP.

Surgery.—Principle articles are on ABDOMEN, SURGERY OF; APPENDICITIS; BONES, DISEASES AND INJURY OF; BRAIN, SURGERY OF; CANCER; DENTISTRY; EAR, NOSE AND THROAT, DISEASES OF THE; HEART AND LUNG, SURGERY OF; HERNIA; INTESTINAL OBSTRUCTION; JOINTS AND LIGAMENTS; MAMMARY GLAND, DISEASES OF; OPHTHALMOLOGY; ORTHOPAEDIC SURGERY; PERITONITIS; SEPSIS; SKULL, SURGERY OF; SPINAL COLUMN, SURGERY OF; SPINAL CORD; UROLOGY; VENEREAL DISEASES. Important shorter articles are on BLOOD-LETTING; BURNS AND SCALDS; CLEFT PALATE AND HARE-LIP; CLUB-FOOT; FISTULA; FRACTURES; HAEMORRHOIDS; PHLEBITIS; REPRODUCTIVE SYSTEM, ANATOMY OF; BLADDER AND PROSTATE, DISEASES OF; DIGESTIVE ORGANS, DISEASES OF; TETANUS; VARICOSE VEINS; WOUND. In addition numerous small articles of about a quarter page are given on subjects of surgical interest.

Medicine.—In this subsection is included the greater number of subjects contained in a single subsection. Besides important articles on MEDICINE, HISTORY OF; MEDICINE, GENERAL; MEDICAL EDUCATION; MEDICAL LEGISLATION; MEDICAL JURISPRUDENCE and MEDICAL RESEARCH, authoritative articles are presented on ALIMENTARY SYSTEM, DISEASES OF; ANAEMIA; CHILDREN, DISEASES OF; DIABETES; DIAGNOSIS; DIPHTHERIA; ENCEPHALITIS LETHARGICA; EPILEPSY; EPILEPTIC FIT; GOUT; HEART, DISEASES OF; HYDROPHOBIA; INFLUENZA; INSANITY; KIDNEY, DISEASES OF; LIVER AND GALL-BLADDER, DISEASES OF; MEASLES; METABOLIC DISEASES; PARALYSIS; PARANOIA; PARATYPHOID FEVER; PNEUMONIA; PSYCHOSIS; PSYCHIATRY; RESPIRATORY SYSTEM, DISEASES OF; RHEUMATISM; SCARLET FEVER; SKIN DISEASES; SMALLPOX; TUBERCULOSIS; TYPHOID FEVER; TYPHUS FEVER. Shorter but also authoritative articles cover most of the diseases affecting man, *e. g.*, ANGINA PECTORIS; APOPLEXY; BLINDNESS, CAUSES OF; BRONCHITIS; CONVULSIONS; DEAF-MUTISM; DROPSY; DYSPEPSIA; GASTRIC AND DUODENAL ULCER; GOITRE; HOOKWORM; INSECT STINGS AND BITES; JAUNDICE; LARYNGITIS; LOCOMOTOR ATAXIA; MIGRAINE; NEURASTHENIA; RICKETS; ST. VITUS' DANCE; TONSILLITIS; WHOOPING-COUGH.

Public Health.—Articles are presented on ABATTOIR; SLAUGHTER-HOUSE; ADULTERATION; AMBULANCE; CREMATION; DROWNING AND LIFE SAVING; ENTOMOLOGY: *Medical;* EPIDEMIOLOGY; FOOD, PURE; HOSPITAL and VACCINATION, in addition to general articles on PREVENTIVE MEDICINE and PUBLIC HEALTH.

Tropical Medicine.—Longer articles are on CHOLERA, DYSENTERY, LEPROSY, MALARIA, PLAGUE, SLEEPING-SICKNESS and YELLOW FEVER. Shorter articles include BERI-BERI, BILHARZIASIS, BLACKWATER FEVER, DENGUE, KALA-AZAR, MALTA FEVER, SANDFLY FEVER, SPRUE, SUNSTROKE AND HEATSTROKE, YAWS.

Veterinary Medicine.—The articles included in this subsection are on ANTHRAX, DISTEMPER, FOOT-AND-MOUTH DISEASE, GLANDERS OR PARCY, ABORTION, CONTAGIOUS, PLEURO-PNEUMO-

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Miscellaneous Medical Articles.—Some 40 articles differing in length are given to subjects not easy to deal with in any of the foregoing sections and subsections. Such are those on ADOLESCENCE; AVIATION, MEDICAL ASPECTS OF; BLOODLESS SURGERY; CLIMATE IN THE TREATMENT OF DISEASE; DIET AND DIETETICS; DRUNKENNESS; HOMOEOPATHY; HYPNOTISM; INFANCY; MANIPULATIVE SURGERY; MINERAL WATERS; NURSING; PHOTOGRAPHY: *in Medicine*; PHRENOLOGY; PHYSICS IN MEDICINE; QUACKERY; RED CROSS; REJUVENATION; SEA-SICKNESS; SOMNAMBULISM; STAMMERING; STARVATION; VEGETARIANISM; VIVISECTION; ANIMALS EXPERIMENTATION; MEDICAL SERVICE ARMY; MEDICAL SERVICE NAVY; VITAMINS. In most instances a recent bibliography is appended to the articles and cross-references are numerous

MEDICAL EDUCATION. A sound general education is necessary for the medical as for all other learned professions

I. IN GREAT BRITAIN

In Great Britain before admission to a course of training a boy or girl is required to show in an examination of matriculation, character and standard that he or she has acquired a respectable knowledge of English, a language other than English, mathematics and some other school subjects of the candidate's own selection. Latin is no longer exacted by the General Medical Council (G.M.C.) although in certain universities it is compulsory for students who desire to obtain a medical degree.

The General Council of Medical Education and Registration does not determine directly the requirements of the various licensing bodies, but exercises a measure of control over the doctor's training by deciding the conditions precedent to registration, first as a medical student and finally as a qualified practitioner. Since 1922 the G.M.C. has required an examination in physics and chemistry be passed by him before registration. The gain is two-fold. His school work more efficiently prepares the boy for his profession, and more time is made available in the brief five years, which is the most that can be exacted as a minimum between registration as a student and registration as a qualified practitioner. The council also allows the student to pass the examination in biology immediately after registration. The curriculum recognized as medical carries the student through a succession of stages which merge insensibly one into the other, until his accumulated knowledge and steadily increasing skill justify the conferring upon him of a degree or diploma which admits him to all the responsibilities of medical practice. It is impossible to over-emphasize the statement that the several steps "merge." They are not stepping stones. No subject is left behind when the passing of an examination qualifies a student to approach the next. The examination tests his fitness to approach subject B whilst still carrying forward subject A.

Stages of the Education.—These stages may be defined as (1) The study of the structure of the body and of its behaviour in health, anatomy (*q.v.*) and physiology (*q.v.*), to which two years are assigned. (2) The study of the behaviour of the body when perturbed by abnormal conditions, by malformations, by injury (*see* PATHOLOGY), by the invasion of parasites (*see* PARASITOLOGY) ranging from ultra-microscopic "germs" (*see* FILTER-PASSING VIRUSES) to intestinal worms, an extension of physiology into the domain of disease. (3) The study of physiological changes which result from the administration of various chemical substances, "drugs," already anticipated by the study of the "drugs" which, in health, various organs pour into the circulation, internal secretions (*see* ENDOCRINOLOGY). (4) The study of the possibilities of modifying the behaviour of the body, when diseased, in a beneficial way by administration of drugs. (5) The proper management of the body in health, preventive medicine. (6) The care of the sick and of women in childbirth.

The Object of Medical Training.—With the exception of the changes already referred to, developments in medical education are rather in the manner of presenting knowledge than in the selection of subjects to be studied. When so much of value must be omitted, every subject included in the curriculum should be taught in the most practical way. It must be made a part of the practitioner's outfit, which he can never afford to lose. His knowledge of the anatomy of the living body must enable him to see its organs in their relation to one another as clearly as if it were transparent. In some degree, dissecting room work has given way to surface anatomy and the study of models and frozen sections; although training in the use of scalpel and forceps is still the only means of acquiring dexterity in the surgeon's craft. In physiology, during the first year, the student is in most schools given more practical work than formerly.

The greatest changes have been introduced in the third and fourth years of the curriculum. Physiology has been extended into pharmacology, an ever-growing body of exact knowledge derived from the study, with instruments of precision, of the effects produced upon guinea-pigs and rabbits by chemical compounds of which some, like caffeine and morphine, are vegetable products, whilst others, such as phenacetin, have been prepared synthetically in the laboratory for the express purpose of modifying the behaviour of the body. When used to correct disorders, these various chemical substances, with the apparatus which has been designed for the purpose of studying their effects, belong to the sphere of therapeutics (*q.v.*).

At about this stage in the student's training, bacteriology (*q.v.*), a science which is growing so rapidly as to be for the most part relatively new, claims his attention. The micro-organisms which cause disease present biological problems of the highest interest. Every medical man needs to be expert in the methods of making preparations for identification with the microscope (*see* MICROSCOPY), of using the various culture media and of cultivating the various organisms *in vitro*. And since the effects upon the fluids of the body which they induce can be recognized chemically, a new name, "biochemistry" (*q.v.*), is usually applied to the department of science in which ascertained facts are grouped together. To the physiologist and physician have been opened up the two provinces of serum and vaccine therapy and immunology (*see* IMMUNITY). Provision is made for teaching the principles of various kinds of drugless therapeutics, such as treatment with ultra-violet light (*see* HELIOTHERAPY) with radium and X-rays, or by massage, and the demonstration of the results obtained in special clinics.

Clinical Units.—The most notable modification in medical education made during recent years is the organization of clinical units. Physicians and surgeons still go round their wards at stated hours—usually in the early afternoon—followed by troops of students to whom they point out the features of each case, expound the nature of the malady and explain the reasons for the treatment adopted. But no longer, as formerly, is the student dependent upon "walking the wards," attending lectures and reading about the illnesses of which the cases he has seen are illustrations. The clinical unit is a far more efficient training centre. Its staff consists of a director and three or four assistants. Either the director himself or one of his assistants is a whole-time officer of the university. To the unit are assigned a number of beds—usually 60 or 70—in suitable wards with adequate laboratory accommodation in their near vicinity and an ample supply of apparatus for the examination of the patients and for testing their reactions. An out-patient department is included in the unit.

Students examine chemically and microscopically the blood and excreta. They make every kind of measurement, and as the wards are open throughout the day they have the opportunity of seeing how patients should be treated, nursed, and cared for in every respect. As the teachers of physiology, bacteriology, pharmacology and other subjects visit the clinic from time to time, the student learns under ideal conditions how all that he has been taught combines to fit him for his life-work, the care of the sick and their restoration as speedily as possible to health.

New and Old Systems Contrasted.—Until comparatively recent times students were required to attend a certain amount of hospital practice during their first two years, usually six months. This was a relic of the apprenticeship through which aspirants for admission to medical, as to legal and other profes-

sional guilds, were required to pass. In Britain, this tradition is obsolete at last. No longer is a student required, or even allowed, to listen to bedside disquisitions on maladies of which even the names may be unfamiliar, in terms which carry little meaning to his mind, or to watch the physical examination of organs of which he knows but vaguely the form and situation, and to hear of their perturbations before he knows how they function normally. Not until he knows how the body works in health is he shown how disease may disturb its harmony, or taught the remedial measures which should be adopted with a view to aiding nature to set it right. Too early contact with patients inevitably led to confused thinking and false inferences which had to be corrected by subsequent reading and observation and, it may be added, developed in the tyro a conviction that medical practice consists in "spotting" the disease and administering the drug which will "cure" it. The progressive opening-out of knowledge with the synchronous revelation of ignorance, which is the aim of the modern curriculum, avoids loss of time and secures the highest degree of qualification which the limited period of training allows.

Post-graduate and Specialist Work.—As a result of the careful allocation of his time the modern student finds that he has less opportunity than his forerunners of paying special attention to any branch which may attract him. Diseases of the eye, of the throat, of the ear, of the nervous and other organs, are treated with sufficient fullness for the equipment of general practitioners, but not with the thoroughness necessary to make specialists. The student who proposes to specialize must continue his studies after graduation. An increasing number of graduates who do not propose to devote themselves to a single specialty, but wish to make themselves proficient in particular branches of their work, such as gynaecology for example, defer going into practice, or return from time to time to a medical school in order to keep abreast with advances in knowledge and technique. Post-graduation courses are more numerous and better organized than they were in former days, but they are not yet, in Britain, as complete or as intensive as they might be.

II. IN OTHER COUNTRIES

Other Countries.—In most other countries, progress has followed much the same lines as in Britain. The arrangement of a logical sequence of studies and their integration in the curriculum have been the reformer's aim.

In Japan the sequence of studies is much the same as in Britain; but the minimal length of the purely medical curriculum is four years, following on a course in the preliminary sciences.

In China through a subsidiary board of the Rockefeller Foundation of New York, there has been established a modern medical school. The Rockefeller Foundation has furnished funds amounting to $8,000,000 to build and equip the Peking Union Medical college, and in addition it was in 1921 supporting the institution on the basis of a budget for the year amounting to $500,000. The China Medical Board also aids four other medical schools in China carried on by other organizations.

In Belgium the University of Brussels in 1921 planned a complete reorganization of its medical department. The city, the State and the university co-operated in maturing plans for a modern teaching hospital, and new, well-equipped laboratories on a single site.

In France the medical schools still adhere to the system which they regard as "natural." Their students are encouraged to attend clinics from the date of their inscription in the faculty, and the relegation of all lectures and laboratory work to the afternoons almost compels them to devote the mornings to attendance in the wards and out-patient departments.

BIBLIOGRAPHY.—For detailed information concerning the existing system of medical education in Great Britain consult *Recent Advances in Medical Education in England*, a memorandum addressed to the Minister of Health by Sir George Newman, Chief Medical Officer; and *Medical Education, a Comparative Study*, by Abraham Flexner. (X.)

III. IN THE UNITED STATES

The U.S. Constitution provided no supervision over either medical education or medical practice but left this to the individual States which, with a few exceptions, have established no regulations, in either State Constitutions or laws. The lack of legal safeguards over the chartering of medical schools made it easy for any group of individuals to open them and to grant degrees whether or not they possessed the essential teachers, buildings, hospitals and other equipment The result was a rapid multiplication of medical schools. The first medical school in the United States was organized in 1765 as the Medical school of the College of Philadelphia. In 1800, there were five medical schools in the United States for a population of 5,500,000 people. Thereafter, they increased much more rapidly than the population, reaching 162 in 1906, when there was one medical school to each half million people. The course of instruction consisted at first of two annual sessions of six months each, probably ample for the knowledge of medicine of that time. The student's best instruction, perhaps, was obtained by assisting his physician-preceptor in the care of patients and listening to his explanations.

At first, some of the university medical schools required a baccalaureate degree for admission but, through competition with the increasing number of schools, the requirement was reduced to a high school education. Nevertheless, the better schools attracted many students possessing a college training. Of the graduates of Harvard Medical school up to and including 1840, for example, 65% also held baccalaureate degrees. The medical schools, with some notable exceptions, were scantily equipped, had no hospitals, and few, if any, expert teachers. In the better schools, however, there were teachers who gained great repute because of their knowledge and skill, as well as their teaching ability, and a large proportion of students were attracted to these schools. Demands for improvement in medical education, however, were not lacking. With no legal supervision of the medical schools, that function was voluntarily assumed by the national organization of physicians. The American Medical association was established in 1847, its chief object being the "improvement of medical education in the United States." Investigations made on several occasions resulted in improvements by the better medical schools. In 1877, a medical practice law was enacted in Illinois creating a State board of health. Information was collected regarding all medical schools in the United States and Canada, and a list made of low grade medical schools from which recognition was withdrawn, forcing most of them to close. Under this board, also, in 1892 the medical course was increased from two to three, and in 1896 to four annual sessions of seven months each. Entrance requirements were raised, nominally, to a high school education. The reports of the Illinois State board of health contain the only reliable information regarding medical education during the 20 years prior to 1900.

A change of administration in Illinois in 1892, however, brought sweeping changes in the personnel of the board of health which resulted in a relaxation of the supervision over medical education and practice and in the adoption of several retrogressive measures. With the relaxation of the efficient supervision of medical education in Illinois, the numbers of inferior medical schools again increased until, in 1906, the United States had over half of the world's supply. Educationally, also, its medical schools suffered by comparison with those of other countries. In 1904, however, the American Medical association created a permanent committee whose duty was the improvement of medical education. Besides collecting and publishing statistics, two educational standards were prepared; one for immediate adoption suggesting a high school education, and another "ideal standard" requiring one and later two years of college work for admission, with a further requirement after graduation of a year's internship in a hospital. An annual conference was held to which representatives of universities, licensing boards, colleges and others were invited for the discussion of problems of medical education. Following an inspection, the medical schools were graded in classes A, B and C according to their degrees of excellence and a classification was published in 1910.

With so many medical schools and with educational requirements lower than those abroad, the need was for fewer but better medical schools. During the inspections, therefore, two or more

medical schools in any city were urged to unite and form one better equipped institution. Thus, the number of medical schools decreased from 162 in 1906, to 80 in 1923; but those requiring college work for admission increased from two to 74, and the graduates of these higher grade schools increased from [illegible] to 3,798. In 1910 the Carnegie Foundation for the Advancement of Teaching published its report following a second inspection of medical schools made jointly by representatives of the Foundation and the American Medical association. This report attracted attention to the need in medical schools, of improvements and financial support. The Foundation established no standards and no classifications, those being continued as a function of the Medical association. In 1914, one year of college work was required for admission which in 1918 was increased to two years. Since 1918, therefore, all students in class A medical schools have obtained two or more years of college education, before entering medical schools, and over 65% of all graduates now obtain both baccalaureate and medical degrees. These higher qualifications are essential if students are to master the present highly technical medical curriculum.

Besides higher entrance requirements, medical schools have increased endowments, new buildings, better laboratories, better trained teachers, better dispensaries and hospitals and more efficient methods of instruction. Now, practically every student before graduation has been drilled in the examination and treatment of patients. Over 90% of graduates spend an additional year as interns in hospitals. Physicians must have a better training than was necessary before 1900. With the great increase of medical knowledge the discovery of the germ origin of diseases has resulted in the development of highly technical methods of treatment of great value if employed by well-trained physicians, but dangerous in unskilled hands. Surgery, formerly used mostly in emergencies, is now commonly employed. Serums, antitoxins, vaccines and the X-ray, wisely used, are saving thousands of lives, but may have serious results if carelessly employed. Because of these highly technical methods, hospitals have become more essential in the care of the sick and have increased both in numbers and size. Through the lack of legal control over hospitals, a voluntary supervision has been assumed by the medical profession. To be approved hospitals are required to possess staffs of competent and reputable physicians, the essential equipment and an efficient routine for the care of sick and injured people.

Bibliography.—Illinois State Board of Health, *Reports* (1880–94); *Journal A.M.A.*, Educational numbers, August each year (1903–28 incl.); U.S. Commission of Education, *Chapters on medical education* (1912–28). (N. P. C.)

MEDICAL JURISPRUDENCE deals with the relationships of law and medicine. A registered medical practitioner is one whose name appears on the register kept by the General Medical Council established under the Medical Acts of 1858 to 1886 to set up standards of professional knowledge, to keep a register of men and women who reach this standard and to deprive of their qualifications those whom the council finds guilty of "infamous conduct in a professional respect." This body is not to be confounded with the British Medical Association, a voluntary association comprising 64% of the medical men and women on the register.

The elements of medical jurisprudence form part of the curriculum of every examining body approved by the General Medical Council. The introductory part of this study treats of the doctor as witness, a medical man being in the nature of things often asked in a court of law to give his opinion as well as to testify as to facts. (*See* Evidence.) At the threshold of this subject stands the question of so-called medical privilege. (*See* Privilege.) Is a doctor bound to disclose in a court of law communications made to him by his patient? The law recognizes no such thing as medical privilege in the sense that there is legal privilege, nor is the reason far to seek. A medical man is consulted about questions which are or ought to be unconnected with the law; a patient does not ask a doctor to undertake his defence in a case before the courts. A medical witness appearing as such should never in any sense be an advocate and must not take sides, whether he be called for the plaintiff or for the defendant. Medical writers themselves hold this ideal up to the profession although in practice it is not always adhered to. Many medical men on graduation take, and all reputable medical men consider themselves bound by, the Hippocratic oath, the relevant part of which is as follows: "Whatsoever in connection with my professional practice or even outside of it I see or hear in the life of men *which ought not to be spoken of* I will not divulge." The italics are important. It is clear that it is required of medical men, as it is required of bankers, that they shall not gossip. When however the law requires it, it is clearly proper to divulge such matters; indeed it will be contempt of court to refuse to do so. On the other hand, it will not be proper to divulge certain matters under any other circumstances, for example, to the executive, who have not the authority, though they often assume it, of the judiciary. (*See* Constitutional Law.)

The notification of Infectious Diseases Act 1889 and many others show that medical privilege is no more recognized by statute law than it is by the common law. The list of acts of parliament which affect medical men is a long and formidable one. Not all of these, however, are considered as forming the subject matter of medical jurisprudence, the majority of them are considered to belong rather to the domain of public health (*q.v.*).

The precision required for elucidation of medico-legal problems will sometimes exceed and sometimes fall short of that required by science; that is to say, the law will at times be content with what may seem rough and ready methods, while at others it is necessary to decide between the diametrically opposed views of medical experts of equal eminence. Obviously the law, by its very nature conservative, must lag a little behind contemporary science, for the interests of justice require not theories nor even hypotheses but facts. The law's *routine* relations are rather with medicine as an art than medicine as a science. This fact is apt to be lost sight of when the so-called expert is extolled at the expense of the general practitioner whose very name denotes that he deals with the realities of life rather than with theories. For this reason medical practitioners enjoy a certain equality in the eyes of the law (nor have we any system as obtains in France where a panel of experts, called *médecins légistes* and consisting of pathologists, toxicologists, gynaecologists and alienists, is drawn up every year by the court). The certificate under the Lunacy Acts may be signed by any registered medical practitioner, although one of the two medical certificates required by s. 5(3) of the Mental Treatment Act 1930 in cases of "temporary treatment without certification" [sic] may be signed only by a practitioner of five years standing approved by the Board of Control. The coroner (*q.v.*) will in difficult cases of course prefer to have the services of a pathologist or of a toxicologist, that is, of men whose reading and practice specially qualify them for the determination of the causes of death, but no such persons are known to the law.

It is difficult to arrange in logical order the subjects falling within the purview of forensic medicine; but a more or less orderly arrangement may be made according to the nature of the court and the case before it. First in date and interest, if not in importance, is the institution, peculiar to the English-speaking peoples (under the common law), of the court of the coroner (*q.v.*) whose duty it is to enquire into all deaths of which the cause is unknown, deaths from violence (accidental or criminal) or in circumstances of suspicion in prisons, lunatic asylums, etc., or from certain notifiable diseases. It is strictly an enquiry and not a trial: there is no suit and there are no parties. The question is—how and by what manner X came by his death. In the great majority of cases death will be found to be due to natural causes, and the investigation of those cases in which the physician in attendance is unwilling or unable to give a death certificate forms the routine work of the pathologist. Some diseases, such as acute haemorrhagic pancreatitis, are almost never diagnosed *ante mortem*. Then again, in cases of sudden death, the physician will be chary of giving a certificate in a case that he has not been attending regularly. Although the coroner enquires into all cases of sud-

den death, he is not always bound to have an autopsy. Some writers, Taylor among them, urge that there should always be an autopsy. Some go further and say that all autopsies should be done by pathologists and not by an "ordinary" medical man. Before 1927 where a certificate was refused and there were no circumstances of suspicion, the publicity of an inquest seemed unnecessarily painful to relatives and not perhaps required by the interests of justice. A useful compromise is found in s. 21 the Coroners Amendment Act 1926 whereby, if there are no circumstances of suspicion and he is not otherwise bound to hold an inquest the coroner may, upon the report of a medical man whom he has instructed to make an autopsy, dispense with an inquest if he thinks fit.

Next in order of frequency will be fatal vehicle accidents which since 1927 must be taken with a jury. It might be thought that in some of these the actual physical cause of death was obvious, as where a man is decapitated by a train. But suppose a man had a stroke and fell under a train: only an autopsy could reveal this and avoid, say, a wrong verdict of suicide, the next commonest case before the coroner.

Last in order of frequency, but of great interest for forensic medicine, will be deaths in respect of which a crime (murder, infanticide, abortion, manslaughter) will be imputed to someone. The duplication of procedure which existed before 1927 has been wisely done away with by the act of 1926 and the coroner, when he learns that someone has been charged with a crime in respect of a body lying within his jurisdiction, adjourns his inquest until after the finding of the criminal court. It is upon the criminal courts that the weapons of forensic medicine have been whetted.

The study of murder (*q.v.*) has a peculiar fascination for many (not necessarily morbid) minds and a vast quantity of material has been collected on this subject. A medical man will usually be one of the first persons on the scene in such cases and it is his duty to note, not only the condition of the body, but also any surrounding circumstances that may be of use in elucidating the crime; for although it is no part of a doctor's business to play the detective, society expects him to take at least as much interest as any other of its members in the suppression of crime. Is an apparent case of suicide, for instance, really one of murder? Did a man found hanging in reality hang himself or was he in fact strangled and then hanged by his assailant?

Louis, a French medical jurist of the Eighteenth century, taught us how to distinguish such cases. A man is found shot or with his throat cut, and a razor or revolver, by him or actually in his hand; was it murder or suicide? These and a host of similar questions are answered in any standard work on forensic medicine. Reading, however, does not make the medico-legal expert. Most of the serious contributions to legal medicine have been made by men who have combined knowledge and experience with the ability to apply both these to an emergency. Some methods, however, have been worked out in the quiet of the laboratory. Of these the most striking is the precipitin test for blood. Blood may be detected by chemical, spectroscopic, microscopic and immunological methods. The first three detect blood but not necessarily human blood, nor was the chemical test (since improved) free from fallacies. The second has no biological specificity while the third enables one to distinguish the blood of the mammalia. The fourth, a veritable triumph of science, enables one to say definitely that the extract of blood-stains examined contains human blood. The stain is extracted with salt solution and added to the serum of a rabbit which has been injected at intervals with human blood: a precipitate will form if the blood is human but not otherwise. The test is done after it has been established by one of the other methods that the stain is blood. In the strictly biological sense the test is generic rather than specific and is given (in a less marked degree) by the anthropoid apes.

The time that has elapsed since death in any given case is an important question to which, in the absence of evidence, the answer cannot in the present state of our knowledge be given with scientific precision. Yet the careful observation of generations has worked out certain rules which allow of an approximation of a fair degree of accuracy. The average rate of cooling of the body is about one degree per hour, depending, however, somewhat on surrounding temperature and moisture, and even, at times, on the mode of death. Post-mortem rigidity comes on three to six hours after death, and lasts, on an average, 16 to 24 hours, while decomposition usually begins on the third day. These are some of the data that are relied on, but they are interpreted in practice with great caution.

If poisoning is suspected, the examiner, under direction of the coroner, sends the stomach and contents and pieces of the solid viscera in sealed jars to the analyst. The study of poisons and their detection is called toxicology. Needless to say the methods have been elaborated with great care, as they must be susceptible of the closest scrutiny.

The crime of infanticide (*q.v.*) is only seven years old in English law. Before that wilful killing of an infant as of any other human being was murder, but the unwillingness of juries to convict led to the Infanticide Act of 1922, whereby the killing of a newly-born child by its mother is made equivalent to manslaughter. Enquiries into the death of infants born alive are not infrequent. The questions for the opinion of the police surgeon, who usually performs the autopsy, will be: Was the child born alive? How long did it live? Was death due to violence, neglect or natural causes? The answers to these questions can be given with precision only by those who have experience of such cases and are acquainted with the fairly comprehensive body of knowledge already acquired—a body of knowledge elaborated, it must be remembered, under the jealous scrutiny of the courts of law when infanticide was murder.

Abortion in law means unlawful abortion, a criminal act, the penalty for which is provided by ss. 55, 58 and 59 of the Offences Against the Persons Act 1861. Abortion, however, means to medical men any artificial termination of pregnancy. There are several indications for the *lawful* termination of pregnancy and their common factor is the danger to the mother's life through the continuance of pregnancy; if the foetus is viable its life will, if possible, be preserved. In criminal abortion on the other hand, it is the mother's convenience that is studied and the act is aimed against and is intended to destroy the ovum or foetus. Lawful abortion will be marked by deliberation, consultation with professional brethren, and the asepsis of the operating theatre. Criminal abortion will be hurried, secret and often septic and unskilful.

Space does not allow the consideration of the numerous other offences against the person which are comprised in legal medicine. The various kinds of manslaughter need not detain us, but mention must be made of the increase in the number of convictions in recent years, due to the enormous development of motor transport. Where, *e.g.*, the driver was "drunk in charge" of a vehicle, criminal negligence will be hard to rebut. The criteria of drunkenness are a subject which is not purely medical. In this condition akin to insanity (*q.v.*) the factor of conduct looms so large that others besides medical men claim to be able to give an opinion. In the navy, *e.g.*, the criterion is: "Is the man fit for duty?" and it is the officer of the watch who applies it, unless the man asks to see the surgeon.

Turning now to civil causes, medical evidence will be required in inquisitions upon lunacy, sometimes in actions upon wills, in actions under Lord Campbell's Act, under the Workmen's Compensation Acts and in matrimonial causes. In connection with workmen's compensation the question of malingering has sometimes to be considered, a subject more familiar to medical men in countries which have adopted conscription. In divorce and in legitimacy cases the period of gestation will sometimes be an issue. After much learned argument there is now pretty general agreement that the period can, in exceptional cases, be as much as 300 days, which happens to be the figure fixed by the XII. Tables. (*See* ROMAN LAW.)

The fact that a medical man may be compelled to disclose in a court of law information obtained from a patient who has consulted him on the faith of the secrecy promised by the Venereal

Diseases Act would seem to make it desirable that medical privilege should be accorded, not indeed with regard to this particular matter alone but in all cases which concern neither fraud nor crime nor otherwise the public interest. (F. T. G.)

UNITED STATES

Medical Jurisprudence deals with the reciprocal relations of law and medicine, using the latter term in its broadest sense. The application of medical knowledge in legal trials is designated forensic medicine. In the United States, the practice of medicine is restricted to licensed physicians, the issuing of licences, as also the regulation of practice, being in the main the function of the individual States. Exceptions include particular Federal laws, such as the act regulating the use of narcotics, popularly known as the Harrison Act, and the act restricting the medicinal use of alcoholic medicinals, known as the Volstead Act. Closely allied is the Food and Drugs Act of 1906, legalizing drug standards.

In presenting evidence of service to a patient, the elements to be established are: the employment, the performance of the service and the value of the service. An original entry of the actual transactions is generally receivable in evidence and is a valuable record. The calling on or of a physician is generally accepted as evidence of employment. Unless there are definite circumstances indicating a contrary relation, the person treated and not the person calling the physician is liable.

By statutes differing in the various States, workmen receive compensation from employers when injured in the pursuit of their employment. The Workmen's Compensation Law of the State of New York provides that the employer must furnish the medical, surgical or other treatment which "the nature of the injury or the process of recovery may require." The employee is not entitled to recover from the employer for expenditures for such services unless, after request, the employer has refused or failed to provide promptly such treatment; nor is a claim of any attending physician valid unless within 20 days from the first treatment he furnish to the employer and to the industrial commissioner, on a prescribed form, a report of the injuries and treatment. The delay may be excused by the board. All fees are subject to regulation by the board and are limited to such charges as prevail in the community for similar treatment of injured persons of a like standard of living. Under this law a large portion of the cases treated is by physicians specializing in compensation work and in clinics of the insurance carriers. Physicians not on the preferred lists of the insurance companies continually experience difficulties over their bills.

The treatment of a patient obliges the physician to possess the ordinary knowledge of his profession and to exercise the ordinary skill. Failure to do so, including wilful neglect, renders him liable for malpractice. A mistake in judgment does not render him liable. Failure to take an X-ray, where the usual practice is to do so, has been construed by the courts as negligence. Wilful unlawful acts towards a patient constitute a second division of malpractice. A third includes acts forbidden by statute, such as the production of criminal abortion or the treatment of a patient while the physician is intoxicated.

Under the Hippocratic oath, physicians regard communications from patients as privileged. Under the English rule of law, the courts do not so recognize them, but in the United States communications are made privileged by statutes in the following States: Group I., in which the patient's consent is necessary for a disclosure: California, Colorado, Idaho, Iowa, Minnesota, Montana, Nebraska, Nevada, New York, North Dakota, Ohio, Oregon, South Dakota, Utah, Washington, Wyoming. Group II., in which the patient waives privilege, if he offers himself or his physician as a witness: Colorado, Kansas, Oklahoma, Oregon. Group III., in which the presiding judge of a superior court may compel disclosure if he deems it necessary to a proper administration of justice: North Carolina. Group IV., in which the statutes are silent on the subject of waiver: Indiana, Kansas, Michigan, Wisconsin. In the Federal courts, in trials at common law the laws of the respective States apply, except where otherwise provided; in a criminal prosecution the privilege secured by State statutes [illegible]

When a physician is called upon as a witness in court merely to relate facts which he has observed, including inferences and deductions which all men are accustomed to make, he is governed by the rules applicable to an ordinary witness. When called upon to explain or interpret facts by reason of his special knowledge, he becomes an expert witness. As an ordinary witness he is subject to subpoena. If the issue concerns a charity patient, the subpoena must be issued by the judge of the court, in some jurisdictions. It is optional with the physician whether he act as an expert witness. In the latter capacity, by reason of his employment by a particular litigant, he is confronted with the possibility of bias which should be avoided. There is criticism of the choice of experts by litigants and resulting conflicting views. To an extent such conflict is due to the relative stability of law with its consequent lagging behind contemporary medical knowledge; experts, especially alienists, thus frequently testifying from different points of view. General medicine, surgery, pathology and toxicology afford less basis for intelligent differences of opinion.

There is no right of property in a dead human body, but duties are imposed upon public officers and next of kin to protect the body from violation and to see that it is properly disposed of and subsequently protected. They may authorize a necropsy to the extent of ascertaining the cause of death. The coroner or other officer is authorized by statutory enactments, varying in detail in the different States, to order a necropsy and such further examination as may be required when, in the discharge of his official duties, it is deemed necessary in cases of sudden death or where there is suspicion that a crime has been committed. If a person dies in one locality and the body is transported to another, the officers where the body is located have jurisdiction. (E. E. Sm.)

MEDICAL LEGISLATION, though of great antiquity, has only recently taken a prominent place in the statute books of civilized countries. In the last 20 years, statutes have been passed in many countries creating or reorganizing the central public health authority. The Ministry of Health for England and Wales created by the Act of 1919 took the place of the Local Government Board with all its powers and duties and, as regards public health, also those previously exercised by the Board of Education and other departments. Power was further created to transfer from the ministry duties which were not incidental to health.

Ministries of Health have also been established in Canada (1919), the Union of South Africa (1919), Poland (1919), New Zealand (1920), France (1920) and Rumania (1923). A Department of Public Health for the Commonwealth of Australia was created in 1921, and a General Directorate of Public Health in Spain, by a royal decree of 1922.

Zymotic Diseases.—In Australia, New Zealand and the Union of South Africa comprehensive regulations regarding the notification and control of infectious diseases were included; similar regulations were issued in Austria (1913), the Straits Settlements (1915), Peru (1916), Chile (1918), Sweden (1919), Brazil (1921) and Venezuela (1921). A Polish law of 1920 created the office of special commissioner for dealing with epidemics, and a French decree of 1920 instituted a mobile unit equipped with laboratories.

Vaccination.—By a law of 1914, vaccination against smallpox (*q.v.*) becomes compulsory in Siam whenever the health administrator deems it necessary; in the Straits Settlements (1915) it is compulsory, and re-vaccination also can be made compulsory in the face of danger; in France (1915) vaccination and re-vaccination can be made compulsory by decree, but (1918) vaccination is compulsory for state officials. Chile (1918) has compulsory vaccination in the first, 10th and 20th years of age; in Venezuela (1921) there is infant vaccination and re-vaccination every seven years, failure to comply barring from a large number of employments. In Poland (1919) there is compulsory vaccination for infants, and again at seven years. In Tunis (1922) vaccination against smallpox is compulsory, and also against typhoid, cholera and plague, if there is danger of an epidemic. Uruguay (1923) has compulsory vaccination in the first six months, and again in the 10th and 20th years. A Polish law of 1920 makes vaccination

against typhoid fever and cholera compulsory for doctors, nurses, employees at waterworks and for various others.

Tuberculosis.—Anti-tuberculosis legislation has been put into force in various directions. Tuberculosis schemes and the legislation involved are discussed in the article TUBERCULOSIS. The Milk and Dairies (Consolidation) Act, 1915, of Great Britain, provided, *inter alia,* for the registration of dairies and the inspection of dairies and herds; and prohibits the sale for human consumption of milk from a cow with tuberculosis or other specified diseases of the udder. The Milk (Special Designation) Order, 1922, of the British Ministry of Health instituted the licensing of classes of milk, namely certified, Grade A (tuberculin tested), Grade A (non-tuberculin tested) and pasteurized; and prohibited the sale of milk under a designation to which it is not entitled.

The British Public Health Act, 1925, section 62, authorizes a court of summary jurisdiction to order the removal to a suitable hospital or institution, of any person suffering from pulmonary tuberculosis in an infectious stage, when a source of danger to others, either from lack of proper accommodation or from failure to observe sanitary precautions. In Denmark, laws of 1912, 1918 and 1919 made compulsory the notification of pulmonary and laryngeal tuberculosis by the doctor in attendance.

A Japanese law of 1919 gives power to examine any person whose calling might make him a source of transmission, to forbid the exercise of a particular calling by such, and to forbid or restrict trading in old clothes, old books and other articles which might carry infection. In Denmark, compulsory isolation of infectious cases is also empowered with certain limitations; and laws of 1918 and 1919 provided for the use of public funds to support hospitals for tuberculosis, sanatoria and convalescent establishments. A French law of 1916 instituted public dispensaries for treatment and for giving instruction in anti-tuberculosis measures. A decree of 1920 laid down regulations for the establishment, working and supervision of sanatoria. An Italian royal decree, 1919, instituted a central anti-tuberculosis committee, and a Swedish royal decree, 1912, regulated subventions to hospitals for treating tuberculosis.

Venereal Diseases.—The English Venereal Diseases Act (1917) prohibits treatment by unqualified persons in areas to which it is applied, when gratuitous treatment has been provided and approved, and prohibits all kinds of advertisements of quack remedies for such diseases. In Sweden (1912) an affected person is obliged to obtain and complete medical treatment; the same applies to the Union of South Africa (1919), where it is also an offence for an infected person to follow certain employments, or to engage such a person in employment; and to Czechoslovakia, where an infectious person may also be removed compulsorily to hospital if necessary, and an examination by a doctor can be enforced where there is reason to suppose that a person is infected with such a disease. In the state of Rio Grande do Norte, Brazil, by a decree of 1921, a special service for the prevention of venereal diseases was created, and provision was made for action against charlatans and for diffusing information regarding modern methods of avoiding the contagion. In Italy, a royal decree (1923), approved of regulations for the prevention of venereal diseases, including the examination and treatment of prostitutes. A Danish law of 1922 obliges a person suffering from venereal disease, in a stage when it may be communicated or transmitted, to inform the other party to a proposed contract of marriage, and this party must be instructed by a doctor before contracting. The parties must make a declaration of freedom from such disease. The same procedure must be adopted if one of the parties suffers from epilepsy.

Housing.—The British Housing Act, 1925, *inter alia,* makes it a duty of the local authority and the medical officer of health to inspect houses, prohibits the erection of back-to-back houses, and gives power to close and demolish houses deemed unfit for human habitation. The Public Health Act, 1925, gives a local authority power to cleanse, disinfect or destroy articles infested with vermin in dwellings, and to oblige a landlord or tenant to cleanse the dwelling; powers are granted for cleansing of the person also. A Belgian law of 1919 instituted the National Society for Housing, amongst its powers being that of destroying unhealthy dwellings; a revising law of 1921 gave power to expropriate such houses and sites as are required. Similar powers were granted to authorities in France by a law of 1915. A law of 1922 codifies the laws relating to working-class dwellings.

Infant Welfare.—The British Notification of Births (Extension) Act, 1915, extended the act to areas in which it had not been adopted. A Belgian law of 1919 instituted the national work for infant welfare. In France a law of 1917 provided financial help for necessitous women in connection with child-birth, and when the mother nurses the child assistance continues for a period of 12 months. In Germany (1922) help is given to women in the same circumstances, insured and uninsured. An English Act of 1920 regulates the employment of children, young persons and women in industrial occupations; and a Peruvian law of the same year is a similar measure.

Food.—The English Public Health (Milk and Cream) Regulations, 1912, prohibited the addition of any preservatives to milk intended for sale for human consumption, any thickening to cream or preserved cream or any preservatives to cream with less than 35% of milk fat; the only permissible preservatives in cream intended for human consumption were boric acid, borax, a mixture of these, or hydrogen peroxide. By an order (1917) no more than 0·4% of boric acid might be added and the cream must be sold as preserved cream and labelled as unsuitable for infants and invalids. In 1925 the addition of boric acid was prohibited altogether. Public Health regulations, 1923, fixed the minimum percentage of milk fat in dried milk of various descriptions, and that of milk fat and total solids in condensed milks. Containers must declare the contents, and skimmed milk be labelled as unfit for babies.

Drugs.—Most countries have legislated to restrict the use of opium, cocaine and related substances. The English Therapeutic Substances Act, 1925, regulates the manufacture, sale and importation of serums, vaccines, salvarsan, insulin, etc. Other countries have legislated similarly. (R. Sc.)

UNITED STATES

U.S. Public Health Service.—This Federal activity originated in 1798, by an act providing medical relief to merchant seamen. The service was then known as the U.S. Marine Hospital Service. Legislation reorganizing the service and authorizing the appointment of a surgeon general was passed in 1870. In 1889 and in 1902 laws were passed effecting further reorganization and in the latter year the hygienic laboratory, established in 1887, was placed on a more effective basis and the name of the service changed to the U.S. Public Health and Marine Hospital Service. The service was further enlarged in 1912 and the name changed to the U.S. Public Health Service.

State Health Departments.—The health department of the District of Columbia was established in 1822. The establishment of State health departments was in the following chronological order: Louisiana (1855); Massachusetts (1869); California (1870); Minnesota and Virginia (1872); Michigan (1873); Maryland (1874); Alabama (1875); Wisconsin (1876); Illinois, Mississippi, New Jersey, North Carolina and Tennessee (1877); Connecticut, Kentucky, Rhode Island and South Carolina (1878); Delaware (1879); Iowa and New York (1880); Arkansas, Indiana, New Hampshire and West Virginia (1881); Missouri (1883); Kansas, Maine and Pennsylvania (1885); Ohio and Vermont (1886); Florida and North Dakota (1889); Oklahoma (1890); Nebraska and Washington (1891); Colorado and Nevada (1893); South Dakota (1895); Utah (1898); Montana and Wyoming (1901); Arizona, Georgia, Oregon and New Mexico (1903); Idaho (1907); Texas (1909).

Notifiable Diseases.—Michigan was the first State to pass legislation providing for a comprehensive system for notification of diseases (1883). Massachusetts followed in 1884. Modern legislation in the several States either specifies the diseases to be reported, designates that certain classes of diseases shall be reported, as "all contagious diseases," or confers on State health departments the right to promulgate regulations covering the subject. Requirements vary as to whom the report is to be made.